SECHELT AREA

PENDER HARBOUR WATER QUALITY ASSESSMENT AND OBJECTIVES

BC Environment

Water Management Division

MINISTRY OF ENVIRONMENT, LANDS AND PARKS
PROVINCE OF BRITISH COLUMBIA

SECHELT AREA

PENDER HARBOUR WATER QUALITY ASSESSMENT AND OBJECTIVES

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SUMMARY

This report assesses the water quality of Pender Harbour, including Bargain Bay, on the Sechelt Peninsula. Water quality objectives are set to protect aquatic life, wildlife, primary-contact recreation, and shellfish harvesting for human consumption. All objectives are provisional pending collection of additional data. A monitoring program is recommended to check whether water quality objectives are being achieved, to finalize provisional objectives that have been proposed, and to increase our understanding of environmental quality in Pender Harbour.

The main water quality concerns in Pender Harbour relate to leachate from septic tile fields and agricultural runoff, as well as sewage effluent and other contaminants originating from boats. These sources have caused elevated faecal coliform levels that have resulted in shellfish harvesting closures, but primary-contact recreation in the harbour is not currently at risk. The extent to which the waters and sediments are impacted by other contaminants such as heavy metals is largely unknown until additional monitoring can be conducted. Nutrient enrichment is not considered to be a significant threat in Pender Harbour.

INTRODUCTION

Pender Harbour is a small coastal inlet on the Sechelt Peninsula, approximately 80 km northwest of Vancouver (Figures 1 & 2). The protected and picturesque nature of the harbour is attracting an expanding resident population and supports an increasing tourist trade. This growth has resulted in escalating pressures on the marine waters of Pender Harbour. Increased nutrient and bacterial loading to the harbour along with intense boating, fishing, and other recreational activities have led to concerns over the possibility of deteriorating water quality. These concerns have been given substance by shellfish harvesting closures which have expanded to encompass the entire harbour.

The purpose of this report is to assess the current water quality of Pender Harbour and to develop water quality objectives for use by resource managers. A detailed technical appendix was prepared and forms the basis for the conclusions presented in this report.

OCEANOGRAPHY AND HYDROLOGY

In an embayment such as Pender Harbour that has no large riverine input, the dynamics of water circulation, mixing and exchange will be driven principally by tidal movement. A tidal mixing model predicts that the median flushing time for Pender Harbour should be approximately three days. However, since both entrances to Pender Harbour are characterized by shallow depths, deeper waters of the harbour may under some circumstances remain isolated from overlying water and, consequently, be subject to slower flushing rates.

During months of heavy rain, flushing in Pender Harbour is accelerated due to the entrainment of saltwater by outflowing freshwater (known as "estuarine-type circulation"). The watershed area for the harbour is 58 km^2 and the months of November through March have the heaviest rainfalls, with monthly freshwater inputs averaging in excess of 7×10^6 m^3/month. This is a significant volume in comparison with the total volume of the harbour of approximately 35×10^6 m^3. Estuarine-type circulation models predict that such inputs can result in a flushing time of 6 days or less. Combining this with the predicted tidal flushing time of 3 days results in a combined median flushing time of 2 days or less during the winter months.

WATER USES

Water-based recreational use of Pender Harbour is high with boating and sport fishing being the dominant activities. The harbour has a total of 21 marina-type facilities with a combined capacity in excess of 750 boats. In addition, there are more than 200 small, private docks spread throughout the harbour. Swimmers also use the water in spite of an absence of good quality beaches.

The fisheries resources of Pender Harbour are diverse and encompass important recreational and commercial fish stocks. Several streams entering the head of the inlet support spawning populations of coho and chum salmon as well as cutthroat and rainbow trout. Chinook salmon, rockfish, perch, and herring are all known to frequent the harbour and crabs constitute a well-used recreational fishery. Clams and oysters are abundant in several areas, although these shellfish are currently subject to a harvesting closure due to excessive faecal coliform levels.

Waterfowl are also important users of Pender Harbour with a variety of species overwintering in the surrounding area. A number of locations in the harbour serve as feeding areas for these birds.

Pender Harbour supports very little industrial/commercial activity in the harbour other than the marinas catering to boat-owners and sport fishermen. There is only one waterfront fish processing plant currently in operation, although a number of commercial fishing vessels continue to utilize the harbour's mooring facilities. There is also one active oyster lease in Pender Harbour.

WASTE DISCHARGES

There are three permitted point sources discharging effluent into Pender Harbour, but their combined discharge volumes are low and water quality impacts are negligible. Non-point sources, such as septic tank/tile field leachate, agricultural inputs, and boats, are more likely to influence water quality in the harbour.

Although most homes and businesses around Pender Harbour are serviced by septic tanks with tile fields, local soils are generally poorly suited for the renovation of septic tank effluents. As a result, some effluent leachate reaches the harbour and contributes to nutrient and bacterial loading. Small agricultural enterprises at the eastern end of the harbour are also a source of faecal contamination.

Boats are a significant source of bacterial loading to the harbour. Their sewage discharges tend to be concentrated and, since most boats tend to moor or anchor in relatively shallow water, localized areas of elevated coliform levels can be expected to occur. Boats are also a potential source of a number of metals and fuel-related contaminants. It is expected that these materials may exist at elevated concentrations, particularly in the sediments surrounding large docks or marina facilities.

WATER QUALITY

Most areas of Pender Harbour routinely experience levels of faecal coliforms in excess of current criteria for growing harvestable shellfish. In the eastern portion of the harbour (Gunboat Bay, Oyster Bay, East Bay), these elevated concentrations are attributed primarily to livestock sources. In the main basin of the harbour, high coliform concentrations are probably due partly to land-based septic tank/tile field systems and partly due to boating discharges. In both cases, however, concentrations are normally well within allowable limits for primary-contact recreation.

Septic field leachate, agricultural runoff, and boat discharges are also sources of nutrient (nitrogen and phosphorous) loading to the harbour. Background variability is so great and the receiving volume of the harbour is so large, that nutrient inputs are not anticipated to significantly impact water quality in the harbour. The possibility does exist that deeper waters in the harbour may trap and concentrate nutrients over a period of time, and this may cause brief pulses of enrichment during periods of complete mixing of the harbour.

Bargain Bay, which forms a southern appendage to Pender Harbour, has generally superior water quality due to better flushing. Only very localized areas of this bay surpass shellfish growing criteria and at no time is primary-contact recreation compromised. Nutrient enrichment problems are not expected in this bay.

Non-bacteriological water quality data for Pender Harbour are extremely sparse, but there is slight evidence of possible heavy metal contamination, particularly of the sediments. This is consistent with other reports of metal contamination in association with large numbers of boats. Metals of concern include copper, zinc, lead, and iron. There are currently insufficient data to draw any firm conclusions related to these metals in Pender Harbour. Although no ambient data are available, tributyl tin and polycyclic aromatic hydrocarbons are also of some concern in the harbour because of their known linkage with boats.

Dissolved oxygen levels are somewhat depressed in Pender Harbour, but this is expected in an enclosed bay with restricted flushing.

WATER QUALITY OBJECTIVES

Water quality objectives proposed for Pender Harbour are summarized in Table 1. The objectives are based on working and approved criteria for water quality and on available data on ambient water quality, waste discharges, water uses, and flushing rate. Many objectives are provisional and will require review when adequate data become available or when approved water quality criteria for the characteristics of concern are developed.

Water quality objectives have no legal standing and are not directly enforceable. They can be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. They will guide the evaluation of water quality, the issuing of permits, licences, and orders, and the management of the fisheries and of the Province's land base. They will also provide a baseline reference against which localized water quality can be compared and decisions for basin-wide water quality studies assessed.

Depending on the circumstances, water quality objectives may already be met in a water body, or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for water bodies and for water quality characteristics which may be affected by man's activity now and in the foreseeable future.

The designated water uses for Pender Harbour are for the protection of aquatic life, wildlife, harvesting of shellfish (in Bargain Bay only), and primary-contact recreation. Water and/or sediment objectives have been proposed for the following characteristics of concern: microbiological indicators, nitrogen, copper, zinc, lead, iron, tributyl tin, polycyclic aromatic hydrocarbons, and dissolved oxygen. Oil and grease films are recognized as nuisance conditions that should be minimized to the greatest extent possible.

Most objectives correspond to approved or working provincial criteria for water quality. Exceptions include the objective for microbiological indicators which has been modified to conform to the new Health and Welfare Canada criteria to protect primary-contact recreation (geometric mean ≤350 enterococci/L). Sediment objectives as given in Table 1 for copper, zinc, lead, and polycyclic aromatic hydrocarbons are based on objectives developed for Burrard Inlet, since provincial sediment criteria are not available. There are also no provincial criteria for tributyl tin, so this objective has been set at a maximum of ≤0.001 µg/L in accordance with the Canadian Water Quality Guidelines.

MONITORING RECOMMENDATIONS

A summary of recommended routine water quality monitoring is given in Table 5. Quality Assurance (QA) for the monitoring program should be maintained by adequate sample replication and the testing of field blanks and reference samples in accordance with the Ambient Water Quality Monitoring Program. The recommended monitoring program provides the minimum requirements needed to evaluate whether water quality objectives are being achieved, to finalize provisional objectives that have been proposed, and to increase our understanding of environmental quality in Pender Harbour.

The recommended monitoring program is based upon technical considerations. Regional priorities and considerations may limit or expand this program.

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Figure 1.

Location of Pender Harbour

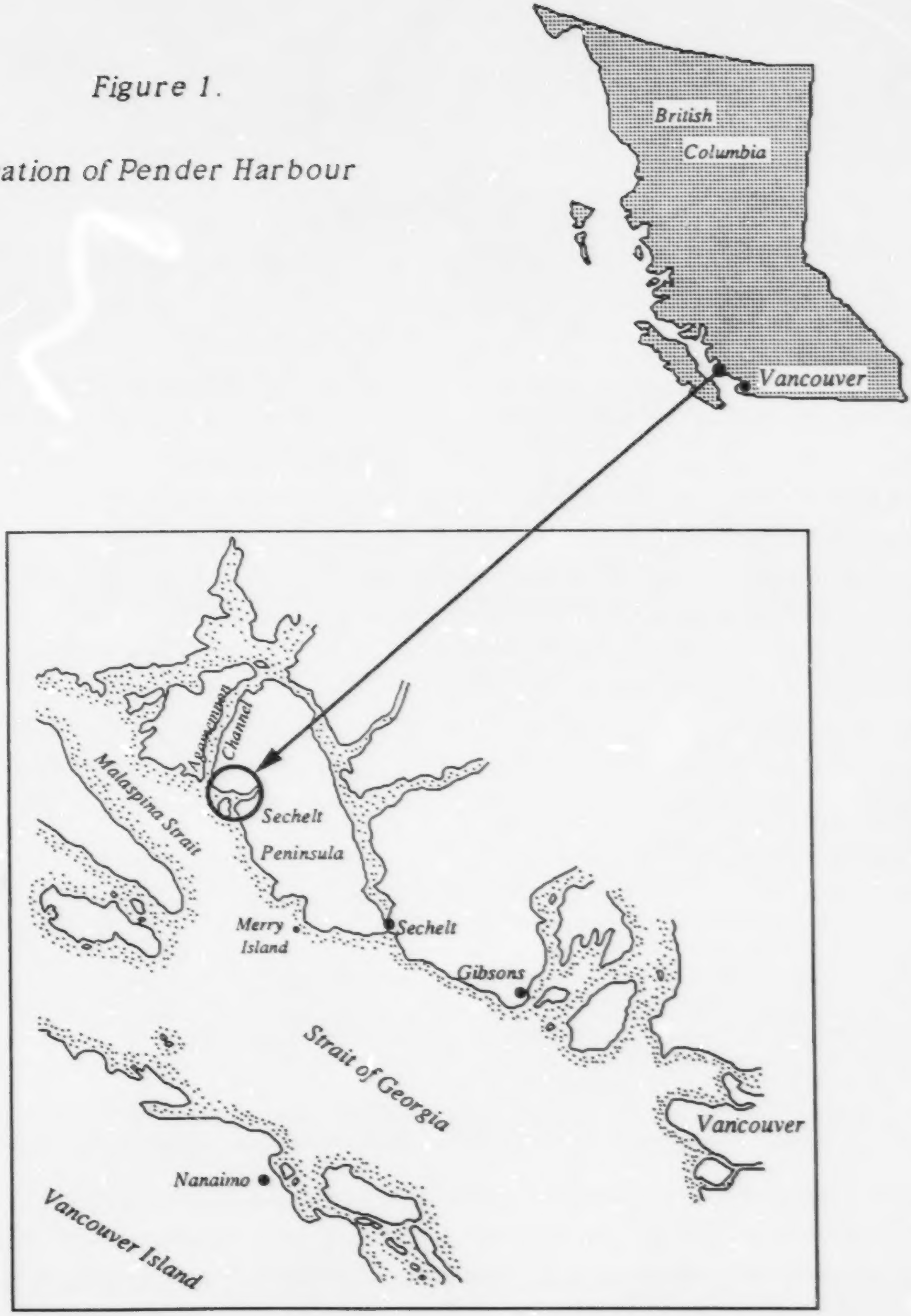

British
Columbia
Vancouver
Agamemnon
Channel
Malaspina Strait
Sechelt
Peninsula
Merry
Island
Sechelt
Gibsons
Strait of Georgia
Vancouver
Nanaimo
Vancouver Island

Figure 2. Pender Harbour Study Area

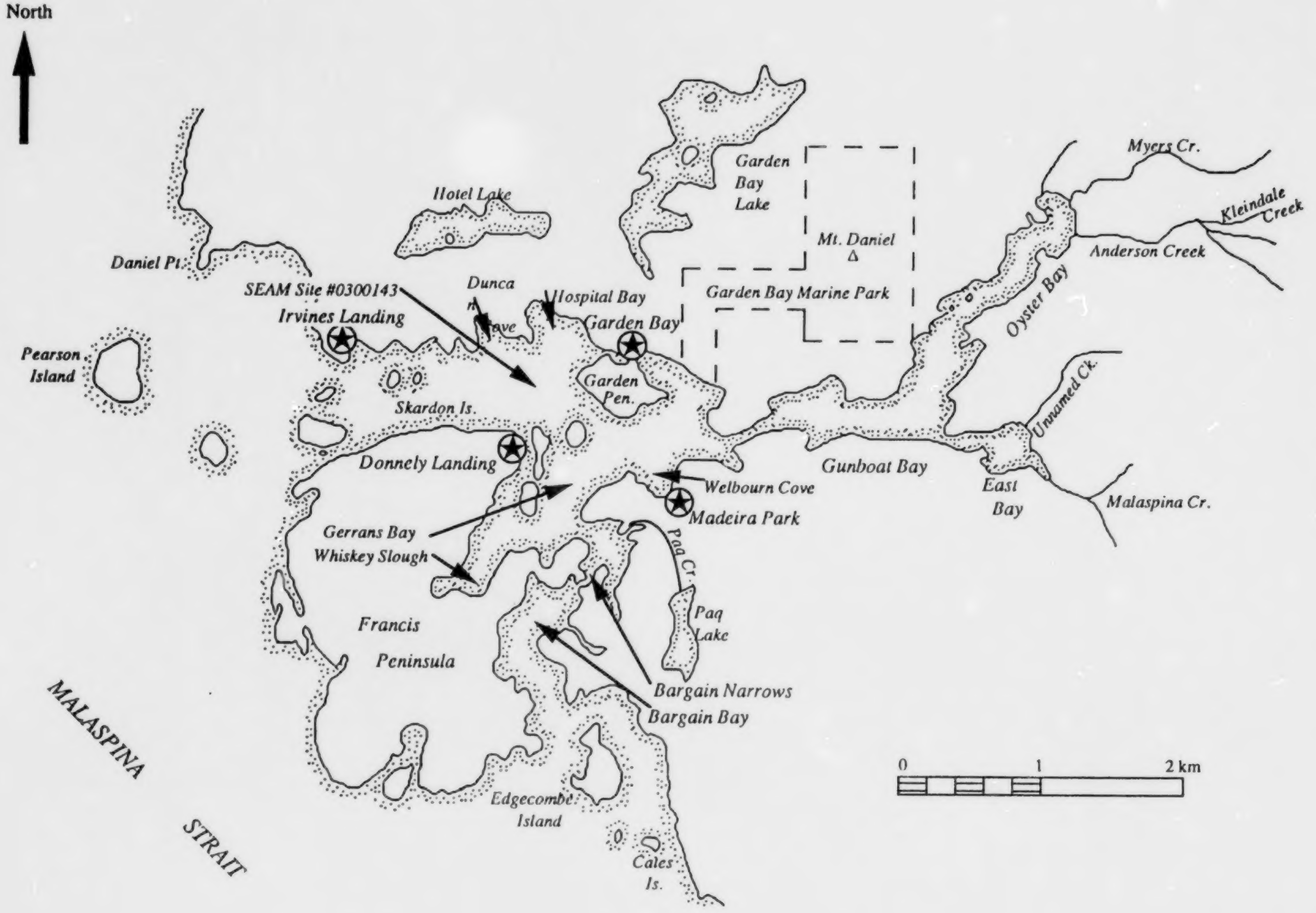

North
Daniel Pt.
Pearson Island
Hotel Lake
SEAM Site #0300143
Irvines Landing
Duncan Cove
Hospital Bay
Garden Bay
Garden Bay Lake
Mt. Daniel
Garden Bay Marine Park
Garden Pen.
Skardon Is.
Donnely Landing
Gerrans Bay
Whiskey Slough
Welbourn Cove
Madeira Park
Gunboat Bay
Paq Cr.
Paq Lake
Francis Peninsula
Bargain Narrows
Bargain Bay
Edgecombe Island
Cales Is.
MALASPINA STRAIT
Oyster Bay
Myers Cr.
Kleindale Creek
Anderson Creek
Unnamed Ck.
East Bay
Malaspina Cr.
0
1
2 km

Table 1. Water Quality Objectives for Pender Harbour

Water Body	Pender Harbour, excluding Bargain Bay	Bargain Bay
Designated Water Characteristics Uses of Concern	Aquatic life, Wildlife, Primary-contact Recreation, Fish consumption	Aquatic life, Wildlife, Primary-contact Recreation, Shellfish harvesting, Fish consumption
Enterococci(1)	≤ 350/L geometric mean	
Faecal Coliforms(1)	not applicable	≤ 14/100 mL median ≤ 43/100 mL 90th percentile
Total Ammonia - N	See Tables 2 and 3	
Total Copper(1)(2)	3 µg/L maximum ≤ 2 µg/L average	
	100 µg/g maximum in sediment	
Dissolved Zinc(2)(3)	0.015 mg/L maximum	
	150 µg/g maximum in sediment	
Total Lead(1)(2)	140 µg/L maximum ≤ 2 µg/L average ≤ 3 µg/L 20th percentile	
	30 µg/g maximum in sediment	
	0.8 µg/g maximum in edible portions of fish and shellfish (wet weight)	
Total Iron	0.05 mg/L maximum	
Tributyl Tin	0.001 µg/L maximum	
Polycyclic Aromatic Hydrocarbons	Sediment objectives only. See Table 4	
Dissolved Oxygen	6.75 mg/L minimum	

(1) Geometric means, medians, averages, and percentiles are based on at least 5 samples taken in a 30-day period. For values recorded as less than the detection limit, the detection limit itself should be used in calculating the statistic.

(2) Sediment concentrations are on a dry weight basis.

(3) This objective also applies to the total zinc fraction if suspended solids are negligible or absent.

The objectives apply to discrete samples from all parts of the water body except from initial dilution zones of fixed effluent discharges. These excluded initial dilution zones may theoretically extend up to 100 m in all directions around the point of discharge, although in practice they will usually be much smaller.

Table 2

Maximum Concentration of Total Ammonia Nitrogen for Protection of Saltwater Aquatic Life (mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	270	191	131	92	62	44
7.2	175	121	83	58	40	27
7.4	110	77	52	35	25	17
7.6	69	48	33	23	16	11
7.8	44	31	21	15	10	7.1
8.0	27	19	13	9.4	6.4	4.6
8.2	18	12	8.5	5.8	4.2	2.9
8.4	11	7.9	5.4	3.7	2.7	1.9
8.6	7.3	5.0	3.5	2.5	1.8	1.3
8.8	4.6	3.3	2.3	1.7	1.2	0.92
9.0	2.9	2.1	1.5	1.1	0.85	0.67
	Salinity = 20 g/kg					
7.0	291	200	137	96	64	44
7.2	183	125	87	60	42	29
7.4	116	79	54	37	27	18
7.6	73	50	35	23	17	11
7.8	46	31	23	15	11	7.5
8.0	29	20	14	9.8	6.7	4.8
8.2	19	13	8.9	6.2	4.4	3.1
8.4	12	8.1	5.6	4.0	2.9	2.0
8.6	7.5	5.2	3.7	2.7	1.9	1.4
8.8	4.8	3.3	2.5	1.7	1.3	0.94
9.0	3.1	2.3	1.6	1.2	0.87	0.69
	Salinity = 30 g/kg					
7.0	312	208	148	102	71	48
7.2	196	135	94	64	44	31
7.4	125	85	58	40	27	19
7.6	79	54	37	25	21	12
7.8	50	33	23	16	11	7.9
8.0	31	21	15	10	7.3	5.0
8.2	20	14	9.6	6.7	4.6	3.3
8.4	12.7	8.7	6.0	4.2	2.9	2.1
8.6	8.1	5.6	4.0	2.7	2.0	1.4
8.8	5.2	3.5	2.5	1.8	1.3	1.0
9.0	3.3	2.3	1.7	1.2	0.94	0.71

g/kg salinity is equivalent to parts per thousand (ppt or $^{0}/_{00}$)

Table 3

Average 5 to 30-Day Concentration of Total Ammonia Nitrogen for Protection of Saltwater Aquatic Life (mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	41	29	20	14	9.4	6.6
7.2	26	18	12	8.7	5.9	4.1
7.4	17	12	7.8	5.3	3.7	2.6
7.6	10	7.2	5.0	3.4	2.4	1.7
7.8	6.6	4.7	3.1	2.2	1.5	1.1
8.0	4.1	2.9	2.0	1.40	0.97	0.69
8.2	2.7	1.8	1.3	0.87	0.62	0.44
8.4	1.7	1.2	0.81	0.56	0.41	0.29
8.6	1.1	0.75	0.53	0.37	0.27	0.20
8.8	0.69	0.50	0.34	0.25	0.18	0.14
9.0	0.44	0.31	0.23	0.17	0.13	0.10
	Salinity = 20 g/kg					
7.0	44	30	21	14	9.7	6.6
7.2	27	19	13	9.0	6.2	4.4
7.4	18	12	8.1	5.6	4.1	2.7
7.6	11	7.5	5.3	3.4	2.5	1.7
7.8	6.9	4.7	3.4	2.3	1.6	1.1
8.0	4.4	3.0	2.1	1.5	1.0	0.72
8.2	2.8	1.9	1.3	0.94	0.66	0.47
8.4	1.8	1.2	0.84	0.59	0.44	0.30
8.6	1.1	0.78	0.56	0.41	0.28	0.20
8.8	0.72	0.50	0.37	0.26	0.19	0.14
9.0	0.47	0.34	0.24	0.18	0.13	0.10
	Salinity = 30 g/kg					
7.0	47	31	22	15	11.	7.2
7.2	29	20	14	9.7	6.6	4.7
7.4	19	13	8.7	5.9	4.1	2.9
7.6	12	8.1	5.6	3.7	3.1	1.8
7.8	7.5	5.0	3.4	2.4	1.7	1.2
8.0	4.7	3.1	2.2	1.6	1.1	0.75
8.2	3.0	2.1	1.4	1.0	0.69	0.50
8.4	1.9	1.3	0.90	0.62	0.44	0.31
8.6	1.2	0.84	0.59	0.41	0.30	0.22
8.8	0.78	0.53	0.37	0.27	0.20	0.15
9.0	0.50	0.34	0.26	0.19	0.14	0.11

The criterion value is obtained by using the average pH, temperature and salinity field values, and is compared to the mean of the measured ammonia concentrations.

Table 4.

Polycyclic Aromatic Hydrocarbon (PAH) Sediment Objectives for Pender Harbour
(µg/g dry-weight)

Lower Weight PAHs	Objective	Higher Weight PAHs	Objective
Σ LPAH	0.5	Σ HPAH	1.2
Naphthalene	0.2	Fluoranthene	0.17
Acenaphthylene	0.06	Pyrene	0.26
Acenaphthene	0.05	Benzo(a)anthracene	0.13
Fluorene	0.05	Chrysene	0.14
Phenanthrene	0.15	Benzofluoranthenes	0.32
Anthracene	0.10	Benzo(a)pyrene	0.16
		Indeno(1,2,3-cd)pyrene	0.06
		Dibenzo(a,h)anthracene	0.06
		Benzo(g,h,i)perylene	0.07

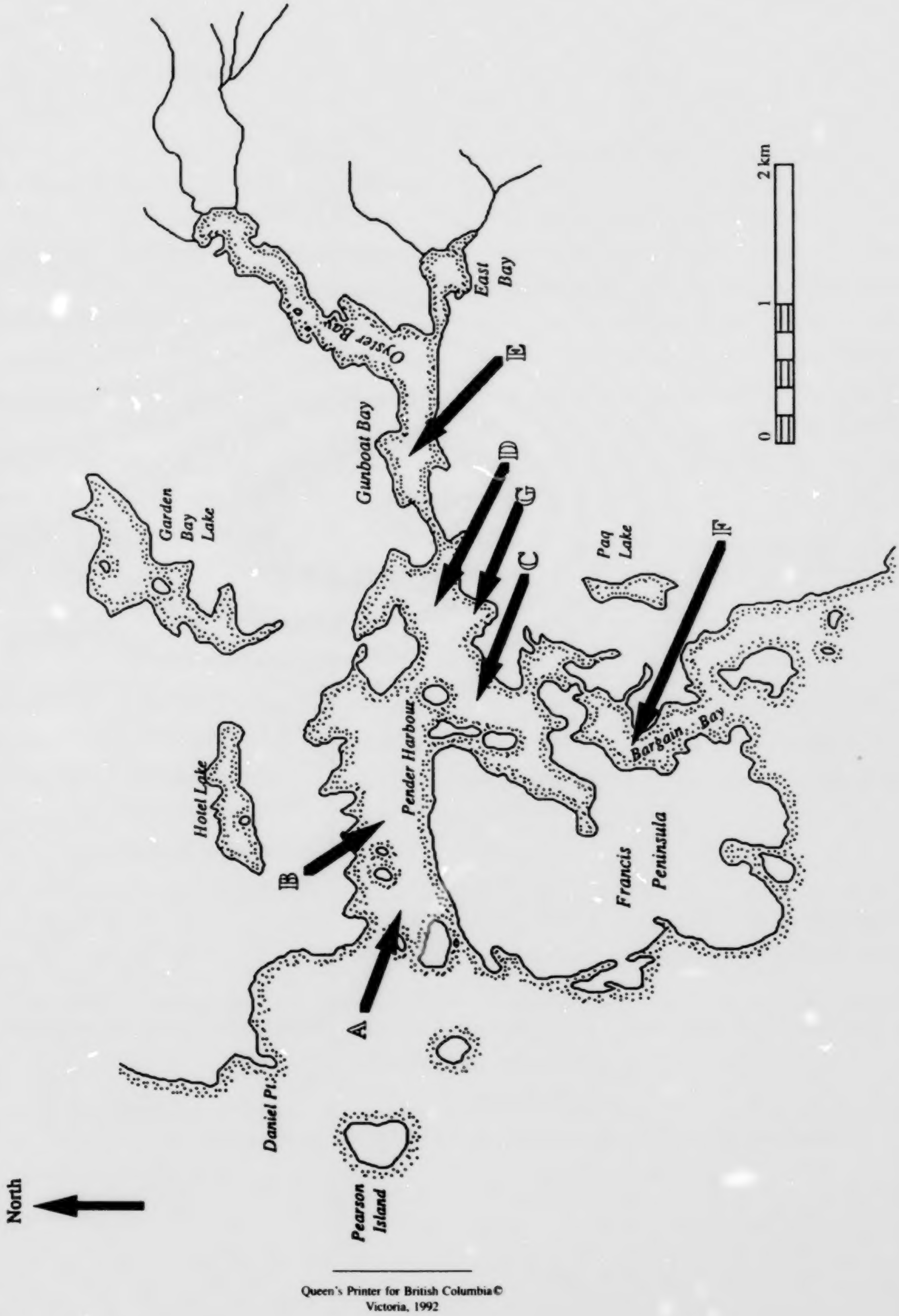
Table 5

Recommended Water Quality Monitoring for Pender Harbour

Sites	Frequency and Timing	Characteristics to be Measured
Several sample sites (suggest 10) should be selected in areas most likely to experience recreational use (i.e., wharves, beaches, etc.). In Bargain Bay, some sites should be chosen in areas supporting shellfish populations.	A minimum of 5 samples taken in a 30-day period. Sampling should be in July/August.	Faecal coliforms and enterococci(1).
Sites A through F (Fig. 3)	A minimum of once per month for one year.	Temperature, salinity, dissolved oxygen. Samples to be collected at 0, 2, 4, 6, 8, 10 m and then every 5 m to the bottom.
Site B (at deepest point in harbour)	A minimum of 5 samples taken in a 30-day period in late summer.	Temperature, salinity, dissolved oxygen, pH, nitrate, nitrite, and ammonia. Samples to be collected at surface, near-surface, mid-depth, and bottom.
Site G (Madeira Park Government Wharf) and Site F (centre of Bargain Bay)	A minimum of 5 samples taken in a 30-day period in late summer.	Total and dissolved copper, zinc, lead, and iron as well as tributyl tin (TBT) to be sampled in surface and near-bottom waters. Sediments to be analyzed for copper, zinc, lead, and TBT.
One shellfish site in Oyster Bay and one shellfish site in Bargain Bay	A minimum of 3 shellfish edible tissue samples taken in late summer.	Total lead content of edible tissues.
One site adjacent to a fuel dock	A minimum of 3 replicate sediment samples taken in late summer.	Polycyclic aromatic hydrocarbons.

(1) Membrane filtration is the recommended analytical technique for these characteristics.

Figure 3. Proposed Monitoring Sites in Pender Harbour


Oyster Bay
East Bay
E
Gunboat Bay
D
G
C
F
Garden Bay Lake
Paq Lake
Hotel Lake
Pender Harbour
Bargain Bay
B
Francis Peninsula
A
Daniel Pt.
Pearson Island
North
0
1
2 km

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SECHELT AREA

PENDER HARBOUR WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

BC Environment
Water Management Division

MINISTRY OF ENVIRONMENT, LANDS AND PARKS
PROVINCE OF BRITISH COLUMBIA

SECHELT AREA

PENDER HARBOUR WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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1. INTRODUCTION

Pender Harbour is a small coastal inlet on the Sechelt Peninsula opening into Malaspina Strait (Fig. 1). It is approximately 80 km northwest of Vancouver, B.C. and is accessible by boat, highway, and float plane. The inlet is characterized by an outer basin encompassing a number of small islands, bays, and peninsulas (Fig. 2). The majority of the local resident population as well as seasonal visitors are concentrated along the shores of this basin. An inner basin beginning at Gunboat Bay is smaller and shallower and supports much less development along its shores. This inner basin terminates in two shallow bays characterized by extensive intertidal flats. Small creeks enter each of these bays. The larger northern bay (Oyster Bay) terminates approximately 5 km inland from Malaspina Strait.

To the south of Pender Harbour, but connected to it by a short narrow channel (Bargain Narrows), lies Bargain Bay. Bargain Bay is largely distinct from Pender Harbour and empties separately to the south into Malaspina Strait. Although not considered part of Pender Harbour proper, Bargain Bay will be included as part of the study area for the purposes of this assessment.

Captain Richards of the *H.M.S. Plumper* named the area after his navigation officer, Daniel Pender, in 1860 (Wolferstan, 1982). The harbour was colonized over the next several decades with the primary centre located at Irvines Landing near the western entrance. Irvines Landing served as a major steamer stop and was the supply centre for the rest of the inhabitants of the harbour. Local industry included commercial fishing, fish processing, logging, and beachcombing.

Pender Harbour remained relatively isolated until the 1950's when paved road access became available. Since that time, the community of Pender Harbour has continued to expand, with the main service centre now located at Madeira Park. The local economy has shifted towards providing services for sports fishermen and recreational boaters. Many commercial fish boats continue to use the harbour on a regular basis, but fish processing and logging no longer constitute significant industries. In addition, the beautiful natural setting of the area attracts many retired people and others to establish permanent homes in Pender Harbour. Summer dwellers put additional development pressure on the area.

The Sechelt Peninsula area is often referred to as the "Sunshine Coast" due to its mild climate and its low rainfall relative to neighbouring Vancouver. Although long-term climatic data are not available specifically from Pender Harbour, Environment Canada maintains a meteorological station at nearby Merry Island (Fig. 1). Thirty year data summaries from this site attest to the mild climate of the area. The annual mean temperature for Merry Island is 10.5°C. The summers are cool with a mean daily temperature in July of 17.6°C and the winters moderate with temperatures in January averaging 3.8°C (Atmospheric Environment Service, 1981). These relatively warm winter temperatures are reflected in the fact that this area normally only experiences snowfall six days out of the year.

Maximum monthly precipitation usually occurs in December (157.2 mm) and the driest month is usually July (38.6 mm). Total annual precipitation (rainfall and snowfall combined) at Merry Island amounts to 994.4 mm. This compares to an annual total precipitation in Vancouver Harbour of 1540.3 mm (Atmospheric Environment Service, 1981).

Prevailing winds in the area tend to funnel up or down Georgia Strait (and Malaspina Strait) with 50% of the wind coming from the east or southeast and 32% coming from the west or west southwest (E. Coatta, pers. com., 1990). No direct wind measurements are available from Pender Harbour, but a high degree of protection from the wind is afforded throughout most of the harbour. The western approaches to the harbour have limited exposure while Bargain Bay is vulnerable to southeast winds. With these exceptions, the majority of the harbour experiences significantly weaker winds than in adjacent "outside" waters. The highly crenulated shoreline of Pender Harbour results in diverse localized wind conditions which vary as to strength and direction.

In summer periods of fine weather, differential heating of the land and water masses can result in wind generation in the Georgia Strait area (Thomson, 1981). Typically, an onshore breeze will develop during the day and offshore breezes will occur at night. If a daytime onshore breeze coincides with a prevailing northwesterly, strong onshore winds can result. Again such winds are only likely to impact the outer (western) approaches of Pender Harbour.

Geologically, Pender Harbour is part of the Georgia Lowland. Marine deposits and deltas in the area indicate that during postglacial times sea level was at least 180 metres higher than it is at present (McCammon, 1977), meaning that the whole of Pender Harbour was once entirely submerged. The area can be characterized as having a shallow overburden of unconsolidated materials with frequently exposed outcrops of bedrock. The nature of these formations have important implications for the water quality of the harbour.

Figure 1.

Location of Pender Harbour

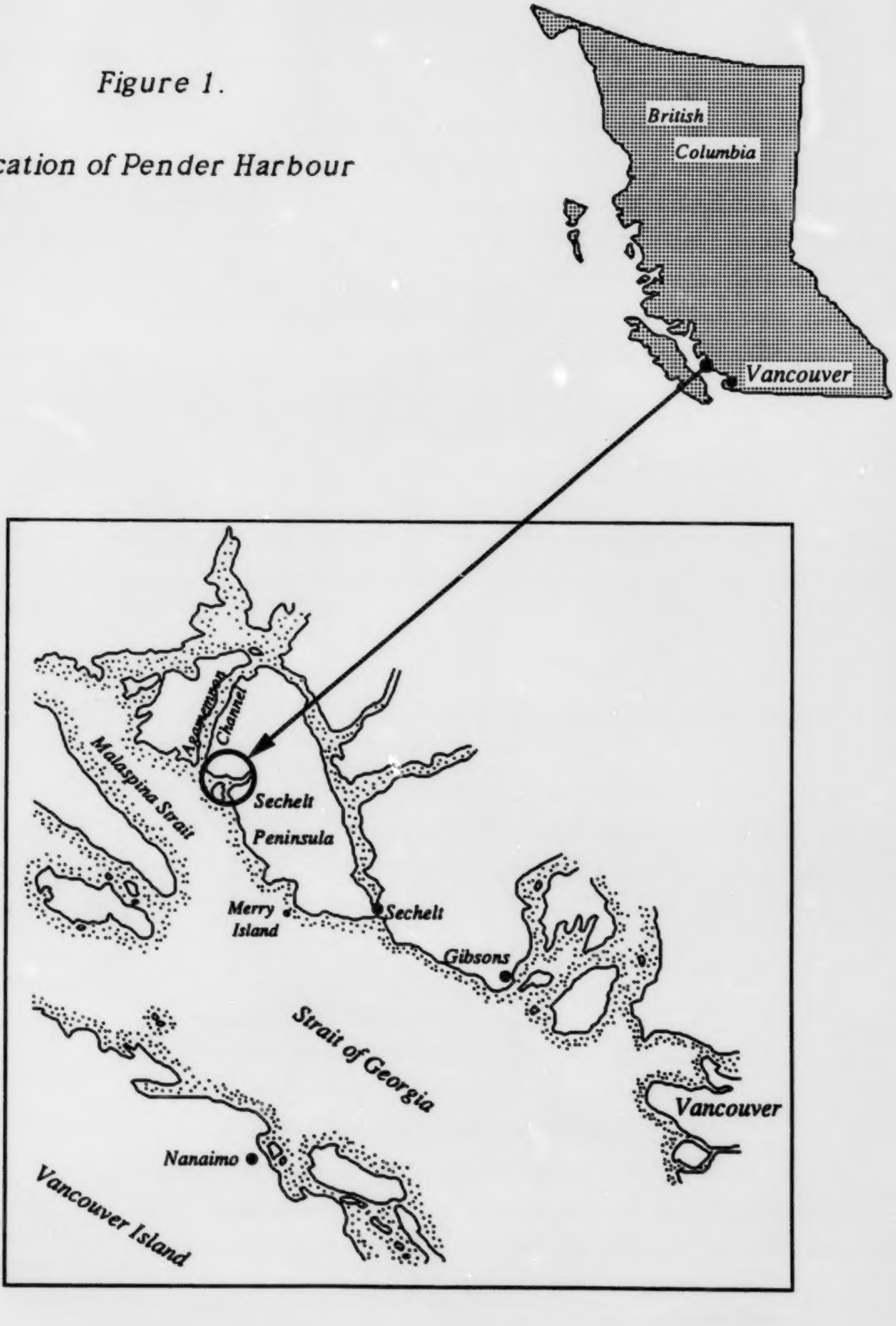
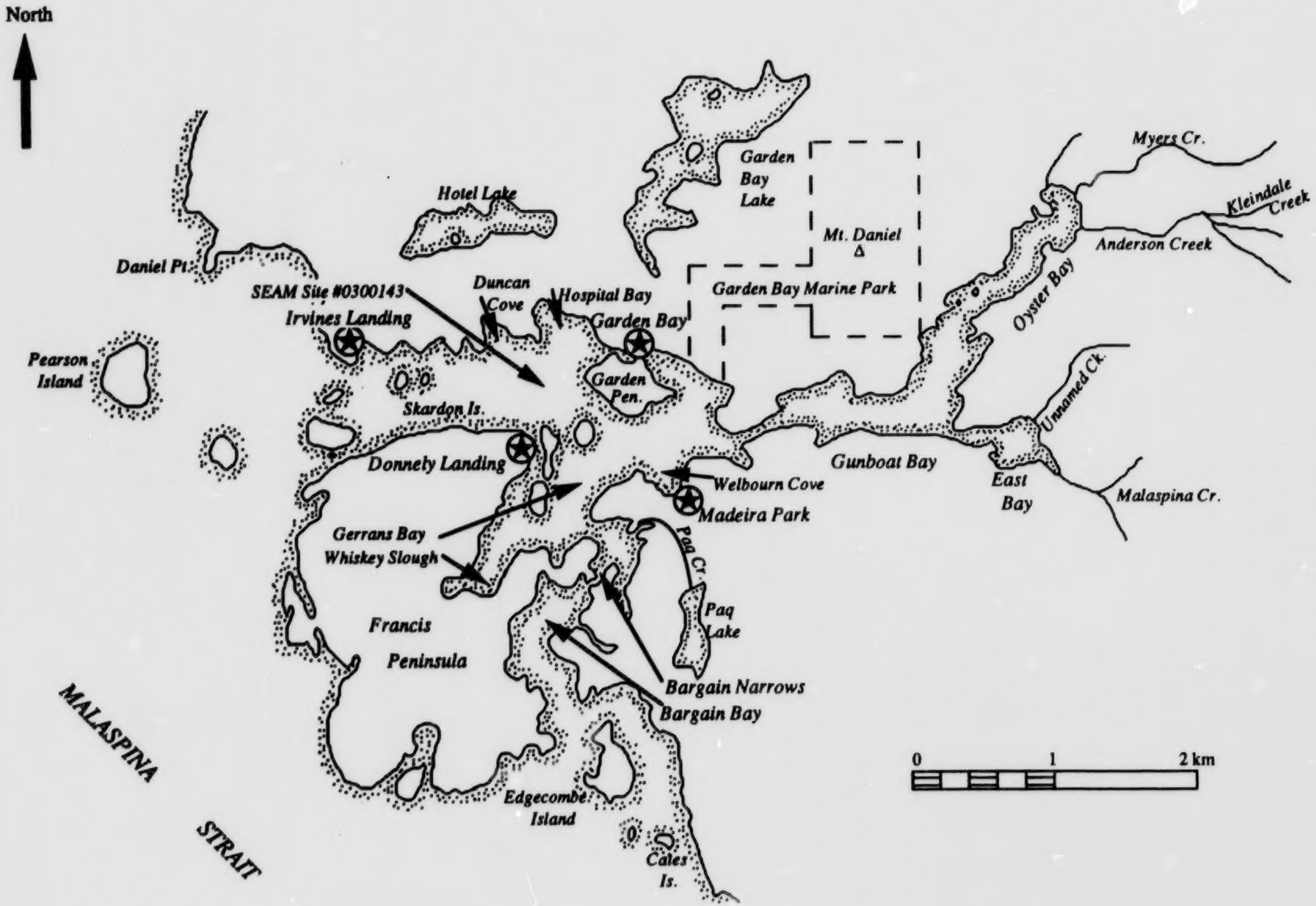

British
Columbia
Vancouver
Agamemnon
Channel
Malaspina Strait
Sechelt
Peninsula
Merry
Island
Sechelt
Gibsons
Strait of Georgia
Vancouver
Nanaimo
Vancouver Island

Figure 2. Pender Harbour Study Area


North
Daniel Pt.
Pearson Island
Hotel Lake
SEAM Site #0300143
Irvines Landing
Duncan Cove
Hospital Bay
Garden Bay
Garden Pen.
Skardon Is.
Donnely Landing
Garden Bay Lake
Mt. Daniel
Garden Bay Marine Park
Myers Cr.
Kleindale Creek
Anderson Creek
Oyster Bay
Unnamed Ck.
Gunboat Bay
East Bay
Malaspina Cr.
Welbourn Cove
Madeira Park
Paq Cr.
Paq Lake
Gerrans Bay
Whiskey Slough
Francis Peninsula
Bargain Narrows
Bargain Bay
Edgecombe Island
Cales Is.
MALASPINA STRAIT
0
1
2 km

2. OCEANOGRAPHY AND HYDROLOGY

2.1 TIDAL EXCHANGE

In an embayment such as Pender Harbour that has no large riverine input, the dynamics of water circulation, mixing and exchange will be driven principally by tidal movement. Bargain Bay to the south is shallow, small, and not restricted at the mouth so it is assumed that this water is regularly flushed with the relatively clean water of Malaspina Strait during every major tidal cycle. Pender Harbour is much deeper and larger than Bargain Bay and is somewhat constricted at the entrance. Such a configuration can dampen the mixing effects of tides and reduce water exchange. For this reason, an attempt was made to estimate the flushing rate for Pender Harbour.

Bowden's (1967) "tidal prism" model was applied to data for Pender Harbour. This model assumes that during the flood tide the incoming water is completely mixed with water in the basin and a portion of this mixture is then removed on the subsequent ebb tide. If V is the total volume of the basin at low water and P is the volume of additional incoming water during the flood, then a fraction $P/(V+P)$ of the mean volume of water is removed during each tidal cycle. Therefore, the flushing time t in tidal periods is:

$$t = \frac{V+P}{P}$$

If the length of the tidal period is known, then the flushing time can be expressed in hours or days.

The tidal prism model was run for an entire year of tides at Pender Harbour to try and determine a mean flushing time. Volumes were calculated by combining digitized area/volume data from Canadian Hydrographic Chart #3535 with tidal height predictions for Irvines Landing for 1988 (I.O.S.) according to the following equation:

$$V = (V_{min}) + (L \times A_{min}) + ((L^2/2H) \times A_{diff})$$

where:

V = volume of water in cubic metres

V_{min} = total volume of water below the low water mark (chart datum) in cubic metres

L = tide height in metres (from tidal predictions)

A_{min} = total area below the low water mark in square metres

H = maximum annual tide height in metres (from tidal predictions)

A_{diff} = difference in area between total area below the low water mark and total area below the high water mark in square metres

The first term of the equation (V_{min}) defines the total volume of water below the low water mark. The second term ($L \times A_{min}$) defines the volume of water above the low water mark, but not covering the intertidal. The third term defines the volume of water above the intertidal area. It is assumed that the intertidal area is covered in proportion to the ratio of the tide height to the maximum tide height (L/H), and that the mean depth over this area is one half the tide height ($L/2$).

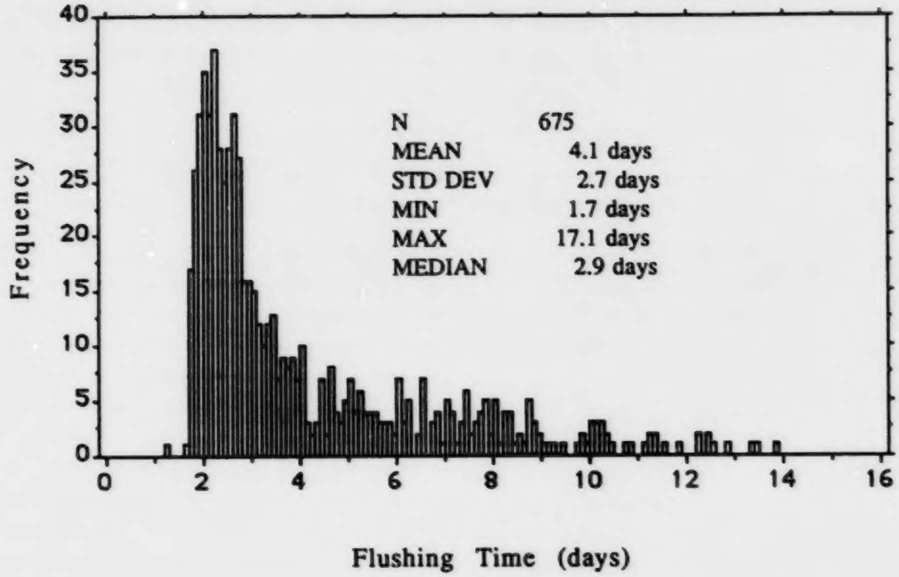
Volumes were calculated for each high and low tide and the values were then inserted into the tidal prism equation for each tidal period. The duration of each tidal cycle was estimated as twice the time interval between high and low tides. All calculations and statistics for this exercise were performed by SAS (V. 5.16) software on a VAX computer.

There were 707 tidal cycles at Irvines Landing in 1988. Some of these tides are considered atypical because of their abnormally short duration. The minimal changes in tide height that usually accompany these tides result in predictions of exceedingly slow flushing rates when the values are entered in the tidal prism model. These anomalous flushing rates were found to seriously bias the data and consequently all tides with less than a 3.5-h interval between tidal maxima and minima were deleted from the calculations. This resulted in the reduction of the database by 31 tidal cycles.

Flushing times in Pender Harbour in 1988 ranged from a low of 1.7 days to a high of 17.1 days. The mean was 4.1 ± 0.17 (95% C.I.) days over the course of the entire year, but since the data is highly skewed (Fig. 3), the median should be used as the best measure of central tendency (Zar, 1974). The median flushing time for Pender Harbour in 1988 was estimated to be 2.9 days.

It is important to realize that 2.9 days is probably a low estimate of tidally induced flushing time since the model is predicated on complete mixing occurring during each tidal cycle. Both entrances to Pender Harbour are characterized by shallow depths. The Skardon Islands near Irvines Landing mark a shallow sill of less than 10 m that extends across the mouth of the harbour. Similarly, Bargain Narrows is very shallow and dries entirely during low tide. On the other hand, the inner portions of the basin are comparatively much deeper with typical depths being 10 - 20 m and with one deep area descending to 44 m. This deeper water will tend to be somewhat isolated from overlying water because of the obstruction to water movement provided by the sills at the entrances. It is therefore unlikely that the entire contents of the basin are effectively mixed with each incoming tide, even though overlying surface water may be rapidly and regularly flushed.

Figure 3. Tidal Flushing Times for Pender Harbour Over a One Year Period



2.2 FRESHWATER FLUSHING

Another mechanism contributing to the flushing of Pender Harbour is the entrainment of saltwater by outflowing freshwater. Many B.C. coastal fjords can be characterized as narrow inlets with substantial rivers or streams at their head. As the freshwater from these rivers moves seaward, it becomes progressively more and more mixed with the underlying saltwater, and entrains the seawater along with it. The loss of surface water is counterbalanced by a matching subsurface inflow of deeper seawater. This sort of water exchange is usually referred to as "estuarine-type circulation" and can cause significant flushing in an inlet. Although Pender Harbour does not conform to the ideal model for estuarine-type circulation, it does have a sizeable watershed with considerable runoff, particularly during high rainfall events. Much of this runoff is collected by the several creeks that drain into Gunboat Bay.

In an effort to quantify the influence of freshwater input on the flushing of Pender Harbour, a series of calculations were performed. First, the watershed area draining into Pender Harbour (excluding Bargain Bay) was determined by digitizing a 1:50,000 topographical map. An area of 57.5 km^2 was calculated. Second, estimates were made of the monthly volume of precipitation falling within this drainage by multiplying the watershed area by the thirty-year average monthly rainfall as recorded at Sechelt (Fig. 1 & Table 1). No direct rainfall measurements were available for Pender Harbour, but it is assumed that Sechelt, being only 26 km down the coast (southeast), would have a similar precipitation regime. These calculations provide an estimate of the amount of water falling within the drainage basin, but do not indicate the actual volume that reaches the harbour. Evaporation and soil retention will reduce the final amount of runoff.

Table 1. Estimated Volume of Precipitation Falling Within the Pender Harbour Drainage Area

MONTH	PRECIPITATION (mm)[a]	TOTAL VOLUME (m^3)[b]
Jan	149.2	8,579,777
Feb	102.0	5,865,531
Mar	97.3	5,595,257
Apr	59.0	3,392,807
May	54.5	3,134,034
Jun	51.7	2,973,019
Jul	41.7	2,397,967
Aug	43.3	2,489,976
Sep	69.6	4,002,363
Oct	122.8	7,061,640
Nov	146.3	8,413,012
Dec	161.6	9,292,842

[a] *From Atmospheric Environment Service, 1981*

[b] *Calculated as watershed area (57.5 km^2) multiplied by 30-year monthly precipitation means.*

Estimates of the percentage of runoff actually reaching the ocean as compared to the amount of overall rainfall can be determined by comparing total watershed precipitation of a gauged stream with actual measured streamflow. No streams in the immediate Pender Harbour area have streamflow gauge data so data for Lang Creek near Powell River were substituted. Powell River is 40 km northwest of Pender Harbour and the Lang Creek watershed is 128 km^2 in area (more than twice that of Pender Harbour). Total annual precipitation at the Powell River airport is 1258 mm, somewhat higher than the 1099 mm recorded for Sechelt (Atmospheric Environment Service, 1981), but it is assumed that percent runoff in the two areas will be similar. Applying the percent runoff figures calculated for Lang Creek watershed to the Pender Harbour watershed will allow an estimate of the actual amount of precipitation draining into the harbour (Table 2).

Note in Table 2 that during some months, percent discharge is greater than 100 percent, which implies that runoff exceeds precipitation. This apparent anomaly is due to the fact that rainfall records for both Powell River and Sechelt are collected at meteorological stations located near to the ocean shore. The watersheds of Lang Creek and Pender Harbour, however, extend some distance inland and these inland areas probably experience somewhat higher precipitation due to the influence of low-lying coastal hills and mountains. Both watersheds also receive some spring snow melt which will tend to elevate runoff during the early months of the year.

Table 2. Predicted Freshwater Input to Pender Harbour

MONTH	PRECIP. (mm) AT POWELL RIVER	TOTAL VOLUME (m^3) AT POWELL RIVER[a]	TOTAL DISCHARGE AT LANG CREEK[b]	DISCHARGE AS A PERCENT OF TOTAL VOLUME	TOTAL VOLUME (m^3) AT PENDER HARBOUR[c]	ESTIMATE OF TOTAL INPUT (m^3) AT PENDER HARBOUR[d]
Jan	165.8	21,222,400	19,070,208	90%	8,579,777	7,721,800
Feb	100.5	12,864,000	17,103,744	133%	5,865,531	7,801,157
Mar	103.2	13,209,600	17,141,760	130%	5,595,257	7,273,834
Apr	65.6	8,396,800	12,467,520	148%	3,392,807	5,021,355
May	58.0	7,424,000	9,133,344	123%	3,134,034	3,854,862
Jun	65.8	8,422,400	4,276,800	51%	2,973,019	1,516,240
Jul	46.2	5,913,600	2,973,024	50%	2,397,967	1,198,984
Aug	59.5	7,616,000	1,387,411	18%	2,489,976	448,196
Sep	71.7	9,177,600	2,348,352	26%	4,002,363	1,040,614
Oct	166.8	21,350,400	8,008,416	38%	7,061,640	2,683,423
Nov	170.4	21,811,200	19,103,040	88%	8,413,012	7,403,451
Dec	184.4	23,603,200	22,766,400	96%	9,292,842	8,921,128

[a] *Calculated as watershed area (128 km^2) multiplied by 30-year monthly precipitation means.*

[b] *From Water Survey of Canada, 1986*

[c] *From Table 1.*

[d] *Total volume of precipitation within Pender Harbour watershed multiplied by the percent discharged.*

Freshwater input to Pender Harbour ranges from a monthly low of 448,196 m^3 in August to a high of 8,921,128 m^3 in December (Table 2). November through March is the period of greatest freshwater input with monthly volumes averaging in excess of 7 million cubic metres. This is a substantial volume when compared with the total saltwater volume of the harbour, which is approximately 25.4 million cubic metres at low water. It is therefore likely that flushing of Pender Harbour is enhanced during the winter heavy rainfall months.

Very few temperature/salinity profile data are available for Pender Harbour, but the Ministry of Environment collected surface and subsurface water samples on five occasions in 1978/79 at a site in the central basin of the harbour (SEAM #0300143, Fig. 2). Using the specific conductivity (lab) values recorded for those samples, it was possible to calculate salinity values using the Practical Salinity Scale (Perkin & Lewis, 1980). The specific gravity anomaly (sigma-T) was calculated using the UNESCO (1979) equation of state for seawater. The results (Table 3) show that during the March sample dates, temperature, salinity and sigma-T gradients between surface and subsurface samples are small. This suggests that the water in the harbour is fairly well mixed during these months. The November sample indicates uniform temperature throughout the water column with the unusual condition of the surface water being slightly denser than the underlying water. This is indicative of very complete mixing. On the other hand, May and August dates show much more pronounced gradients, indicating reduced mixing. This is consistent with the thermal stratification that can be expected to occur in confined water bodies in the summer. Although the data are too sparse to draw firm conclusions, they tend to support the concept of some vertical mixing occurring in the winter, with reduced mixing in the summer.

Table 3. Water Column Profiles in Pender Harbour

SAMPLE DATE	DEPTH (metres)	TEMPERATURE (degrees Celsius)	SALINITY (ppt)	SIGMA-T
Mar 21,1978	0	10.5	25.0	19.1
	20.0	9.5	25.9	20.0
May 17,1978	0	15.0	22.4	16.3
	18.3	12.0	28.1	21.3
Aug 17,1978	0	19.0	22.6	15.6
	13.7	14.0	26.1	19.3
Nov 1,1978	0	10.0	28.4	21.8
	13.7	10.0	27.5	21.1
Mar 14,1979	0	7.0	28.5	22.3
	13.7	8.0	29.7	23.1

Knowing the volume of freshwater coming into an inlet (Table 2), along with surface and subsurface salinities (Table 3), it is theoretically possible to calculate the flushing time of the inlet based on estuarine-type circulation. The *Two-Layer Model* (Bowden,1967) provides a formula for this computation:

$$T = \frac{V(S_2 - S_1)}{S_2 R}$$

where:

T = Flushing time

V = Total volume of water contained in the inlet

S_1 = Salinity of the outflowing (upper) water

S_2 = Salinity of the inflowing (subsurface) water

R = Volume of freshwater input

Table 4 provides solutions for this equation for the five dates for which data are available, but because the data are so limited, the results must be interpreted with caution. Also, reduction in surface salinities may be due in part to the influence of the Fraser River and this could cause flushing rates to be overestimated. Nevertheless, the data suggests that freshwater-induced flushing rates during March are a few days as compared to many months during August. The months of November through February all have higher freshwater discharge volumes than March (Table 2), so it is logical to expect that corresponding flushing rates for these months will be somewhat lower than the 5.2 and 6.0 days calculated for March. These flushing rates are relatively rapid and significantly enhance the overall flushing of the basin. The negative value obtained for the month of November in Table 4 is an anomaly due to the unusual density inversion recorded for that date and should be disregarded.

August has the lowest discharge volume of the year (448,196 m^3), but June, July, and September also have low values (all less than 2,000,000 m^3) and can therefore likewise be expected to have very long flushing periods. Flushing due to freshwater inflow (estuarine circulation) can be considered to be essentially nonexistent during these months. April, May, and October are transition months when freshwater flushing of Pender Harbour will be a minor influence.

Table 4. Predicted Flushing Rates of Pender Harbour Based on Two-Layer Model

SAMPLE DATE	SURFACE[a] SALINITY (ppt)	SUB-SURFACE[a] SALINITY (ppt)	MEAN[b] MONTHLY VOLUME OF HARBOUR (m^3)	VOLUME[c] OF FRESH-WATER INPUT (m^3)	FLUSHING TIME (months)	FLUSHING TIME (days)
Mar 21/78	25.0	25.9	34,961,114	7,273,834	0.17	5.2
May 17/78	22.4	28.2	35,050,199	3,854,862	1.87	58.0
Aug 17/78	22.6	26.1	35,031,991	448,196	10.48	324.9
Nov 1/78	28.4	27.5	35,022,888	7,403,451	-0.16	-4.6
Mar 14/79	28.5	29.7	34,961,114	7,273,834	0.19	6.0

[a] *From Table 3.*

[b] *Calculated from volumes as determined in the Tidal Prism Model.*

[c] *From Table 2.*

2.3 SUMMARY

Tidal exchange is the principal mechanism driving the flushing of Pender Harbour, with an annual median flushing time of approximately 3 days. In fact, this figure probably exaggerates the actual flushing time because the calculations assume complete mixing during each tidal cycle. While such mixing may occur in winter, some of the basin's deeper water will probably remain somewhat isolated during the summer, due primarily to thermal stratification. Wind can induce some mixing of marine water, but Pender Harbour is afforded considerable protection from prevailing winds by the surrounding land masses. Wind-generated mixing is unlikely to extend into deeper waters.

Freshwater input is a secondary flushing mechanism which has an additive effect with tidal exchange. During the winter high rainfall months, estuarine-type circulation may result in a flushing time of 6 days or less. Combining this with the predicted time of 3 days for tidal exchange results in a combined mean flushing rate of 2 days or less.

During the summer months, estuarine circulation does not occur due to greatly reduced precipitation. This means that tidal exchange is the sole mechanism of flushing Pender Harbour during this period. Tidal exchange may also be restricted, depending on the degree of mixing occurring in the basin. If stratification is highly developed, surface waters may be flushed at rates much faster than once per 3 days, while deeper waters may not be flushed for extended periods. A monthly series of temperature/salinity profiles are required to establish definitively the mixing regime within the basin.

3. WATER USES

3.1 RECREATION

Water-based recreational use of Pender Harbour is high with boating being the dominant activity. The harbour is a natural stopping point for vessels heading for Princess Louisa Marine Park, Desolation Sound, and other points north. There is also a small, currently undeveloped marine park within the harbour with limited open anchorage. Garden Bay Marine Park fronts 200 m of waterfront on the shoreline of Garden Bay and provides an access corridor to nearby Mount Daniel (Fig. 2). Pender Harbour is also a popular destination for sports fishermen who launch, moor or rent boats within the harbour. This heavy boating use is reflected by the numerous commercial marinas and wharves spread throughout the area. A survey conducted in January of 1990 showed a total of 21 marina-type facilities with a combined capacity of well in excess of 750 boats (Table 5). Interviews with the managers of these operations indicate that during the busy summer season more than 70% of this capacity is utilized. During the winter months, use drops to around 30%.

In addition to these larger facilities, the shores of Pender Harbour are dotted with numerous small private floats and docks belonging to local residents. An examination of 1987 air photos of the area showed that there are in excess of 200 of these structures. Typically, these docks show intermittent boater use. Another source of boating pressure within the harbour is provided by boaters who anchor their vessels rather than tying up at docks. Residents noted that a number of transient boats anchor overnight (or longer) in the harbour. The most popular anchorages are Garden Bay, Gerrans Bay, and the entrance to Pender Harbour.

Swimmers also use the waters of Pender Harbour. The absence of good quality beach areas and the heavy boating activity restrict swimming somewhat, but many people continue to swim around the numerous government and private docks in the area. Water skiing is also popular in several areas of the harbour. The Public Harbours Regulations of the Canada Shipping Act restrict the speed of vessels in harbours to less than 12.9 km/h, but this does not seem to discourage many of the persistent waterskiers.

Table 5. Boating Facilities in Pender Harbour (1990)

MARINA	LOCATION	AVG. NO. OF BOATS		LIVEA- BOARDS	MAX. CAPACITY	WASH- ROOMS	SHOWERS	LAUNDRY	PUMP- OUT	FUEL	RENTALS	% USA	COMMENTS
		SUMMER	WINTER										
Sportsman Moorage	Garden Bay	35	7	X	35	X	X	X				0	
Seattle Yacht Club	Garden Bay	5 - 12				X	X	X	X			100	All boats are equipped with holding tanks
Garden Bay Hotel	Garden Bay	5	2	X	15							50	
Vancouver Yacht Club	Garden Bay				40?	X	X	X					Recently purchased. Status unclear. Capacity estimated
Headwater Marina	Madeira Park	45	20		45	X	X					0	A few "weekenders" stay on their boats
Madeira Marina	Madeira Park	20 - 25	13		25 - 30	X						50	Overnighters are discouraged
Lowe Resort	Madeira Park	35 - 40			50	X	X	X		X	X	<50	Marina caters mostly to small boats
Lidde Bay Resort	Madeira Park	20	8	X	20	X		X			X	50	
Coho Marina Resort	Madeira Park	55	55	X	85								Bathroom facilities available at trailer camp
Madeira Park Estates	Madeira Park				25								Private moorage for small boats
Duncan Cove Resort	Duncan Cove	80	7	X	80	X	X						
John Henry's Marina	Hospital Bay	12	12		12					X			Owner noted a shortage of bathroom facilities
AB Haddock Marina	Hospital Bay	14	14		14								
Fisherman's Resort	Hospital Bay	35	4	X	56	X	X	X			X	67	
Farrington Cove	Farrington Cove												Large marina not currently in operation
Irvings Landing Marina	Irvings Landing	50	5	X	50	X	X	X		X		25	
Bowsprit Road	Bowsprit Road	>5	5		20								Status unknown. Capacity estimated
Government Wharf	Whiskey Slough	33	26	X	65								
Government Wharf	Madeira Park	69	55	X	90	X						65	
Government Wharf	Hospital Bay	15	12	X	25								
Government Wharf	Irvings Landing	1 - 2	1 - 2	X	2								
Totals		529 - 547	246 - 247		754 - 759								

Table is based on survey and interviews conducted in January of 1990 as well as data provided by the Small Craft Harbours Branch of Fisheries and Oceans (Ryll, 1990). All values given are estimates. For most purposes, an average boat length of 8 m is assumed.

3.2 FISHERIES

The fisheries resources of Pender Harbour are diverse and encompass important recreational and commercial fish stocks. Anderson, Myers and Kleindale Creeks at the head of Oyster Bay all support spawning populations of coho and chum salmon (Tancock, pers. com., 1990). Coho are also known to spawn in Paq Creek and a small unnamed creek in Gunboat Bay. The marine waters of Pender Harbour are used principally by the juveniles of these species as they migrate towards the ocean. The estuaries and sheltered bays of the harbour provide good feeding/rearing habitat as the salmonids adjust to saltwater. A third species of salmon, the chinook, is also found in the waters of Pender Harbour. Unlike the chum and coho salmon, adult chinook stocks are known to be winter residents in the harbour (Tancock, pers. com., 1990).

Other species of fish found in Pender Harbour include cutthroat and rainbow trout which spawn in virtually all creeks emptying into the harbour. All trout and salmon stocks of Pender Harbour contribute to valuable sport and/or commercial fisheries, and many of these stocks are locally enhanced through habitat improvement, flow control structures, and small incubation facilities (Tancock, pers. com., 1990). These populations are heavily fished both in and out of the harbour, and fishermen account for a large proportion of the numerous boaters in the area. Rockfish and perch provide additional year-round fishing opportunities within the harbour.

Pender Harbour has supported significant herring spawns in the past, but stocks of this fish have been in decline in recent years. Herring is an important resource both as a commercial fishery and as a food source for other fish species. Schools of herring still frequent Pender Harbour, but spawning in this area is now very erratic and spotty. The most recent herring spawns occurred in the vicinity of Irvines Landing and Gunboat Bay several years ago (Tancock, pers. com., 1991), but historically, Gerrans Bay and Bargain Bay were noted as preferred spawning habitat (Coastal Resource Folio, 1983).

Other fishery resources within the harbour include a variety of shellfish species. Crabs constitute a well-used recreational fishery within the harbour and are fished year round, particularly in Gunboat Bay and Bargain Bay. The harbour is generally too shallow to provide suitable habitat for prawns, but the deeper approaches to the harbour (i.e., in the vicinity of Pearson Island) yield successful harvests. Clams and oysters are abundant in several areas in the harbour, including Oyster Bay, East Bay, Bargain Narrows, and the head of Gerrans Bay (MacLaren Plansearch, 1981). Officially, harvesting of these shellfish is prohibited due to a sewage contamination closure imposed by Environmental Protection, Environment Canada. In spite of this closure, harvesting of clams and oysters continues to be a common practice according to the local fisheries officer (Tancock, pers. com., 1991).

3.3 WATERFOWL

A variety of diving ducks, other diving birds (loons, grebes and cormorants), gulls and alcids (murres, etc.) have been reported to winter in Pender Harbour (Fish and Wildlife Branch, 1977). A number of locations in the harbour serve as feeding areas for these birds, but the salt marsh of Oyster Bay is particularly noted as important feeding and wintering grounds (MacLaren Plansearch, 1981). Trumpeter swans, bald eagles and oystercatchers have been noted in Pender Harbour and great blue herons reportedly nest in the surrounding uplands. In addition, the Salt Lagoon adjacent to Bargain Narrows has been noted as a feeding area for goldeneye ducks, scoters, buffleheads, Canada geese and trumpeter swans (MacLaren Plansearch, 1981).

Daniel Point ,which marks one of the northern approaches to the harbour, is not within the designated study area, but its proximity to the harbour and the significant bird population it supports make it worthy of note. The point was reportedly a nesting area for a colony of approximately 40 pigeon guillemots (B.C. Provincial Museum, 1976). If this colony still persists, it is one of the largest of its kind in Georgia Strait.

3.4 INDUSTRY

3.4.1 Fish Processing

Industrial use of Pender Harbour has declined in recent decades and has been largely supplanted by recreational use. Some long-time residents believe that water quality within the harbour has actually improved since the 1940's when water-based industries (i.e., fish processing, boatyards) were much more common. Tidal Wave Seafoods at Donnely Landing is now the only waterfront fish-processing plant still operational within the harbour. This company processes a variety of invertebrates, salmon, and other finfish (Twaddle, pers. com., 1990)

3.4.2 Commercial Fishing

Other industrial users include commercial fishermen who use Pender Harbour as a moorage facility. The Whiskey Slough, Madeira Park, and Hospital Bay government wharves provide the principal moorage locations for these vessels, although a few private docks are used too. As can be seen from Table 6 , commercial use of these wharves is substantial but highly variable. Approximately 45 commercial vessels were moored in Pender Harbour during a survey in January 1990. It is expected that fewer fishing boats would be present in the harbour during the height of the fishing season in the summer months. Although all kinds of commercial fish boats use Pender Harbour, gillnetters are the most common.

Moorage is not the only function Pender Harbour provides in support of the commercial fishing fleet. Although commercial fishing does not occur within the confines of the harbour, these waters provide migratory, feeding, spawning and rearing habitat to salmon and herring (as discussed in Section 3.2). These important species ultimately enter the commercial fishery outside the harbour.

Table 6. Monthly Averages for Commercial Boat Use of Government Wharves

YEAR	MONTH	WHISKEY SLOUGH	MADEIRA PARK	HOSPITAL BAY	TOTAL
1987	JUN	*	17	*	17
	JUL	*	7	*	7
	AUG	*	21	*	21
	OCT	*	34	*	34
	NOV	*	37	*	37
	DEC	*	35	*	35
1988	JAN	*	35	*	35
	FEB	*	27	*	27
	MAR	*	28	*	28
	APR	*	30	*	30
	MAY	*	30	*	30
	JUN	*	6	*	6
	JUL	*	4	*	4
	AUG	*	20	*	20
	OCT	14	*	*	14
	NOV	12	18	*	30
	DEC	35	*	11	46
1989	JAN	47	*	*	47
	FEB	*	47	*	47
	MAR	7	6	5	18
	SEP	9	15	4	28
	OCT	10	*	5	15
	NOV	9	9	7	25
1990	JAN	12	9	6	27

Data as provided by Small Craft Harbours Branch (1990)
Asterisks (*) represent missing data, not null values.
Note that in most cases, "Total" values underestimate actual totals due to missing data.

3.4.3 Aquaculture

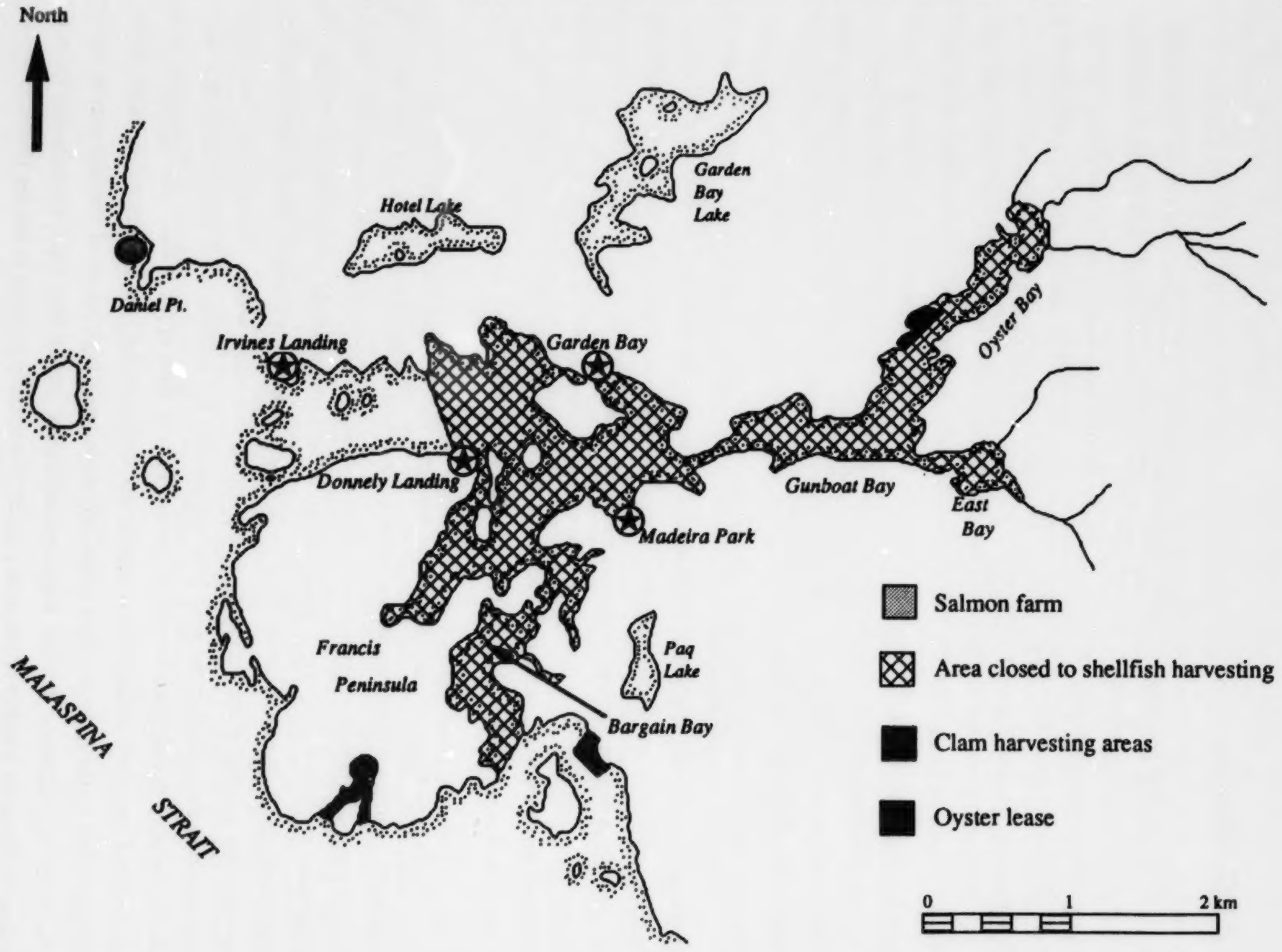
Aquaculture within Pender Harbour is restricted due to heavy boat traffic and unacceptable bacteriological conditions. The extensive intertidal flats of Oyster Bay are well-suited to oyster culture, but bacteriological surveys conducted by the federal Department of Fisheries and National Health and Welfare and by the provincial Department of Health and Hospital Insurance in 1964 closed the area to shellfish harvesting (Arney & Tevendale, 1974). Surveys by various government agencies during subsequent years expanded the closure to Gunboat Bay (1967), Pender Harbour east of Donnely Point (1974), and Bargain Bay (1988). Recent bacteriological surveys conducted by the Environmental Protection Service of Environment Canada (E.P.S.) in October of 1989 confirmed that these waters do not meet minimum sanitary conditions for the harvesting of shellfish (Walker, pers. com., 1989). Figure 4 shows the extent of current shellfish harvesting closures in Pender Harbour.

In spite of these closures, one 4.37 ha oyster lease is still maintained by the Oyster Bay Oyster Company in Oyster Bay (Fig. 4) (Hall, pers. com., 1990). The company also operates a shucking plant. However, before processing or marketing, all oysters produced on this lease must be transferred ("relayed") to a site outside of Pender Harbour for a prescribed period of time to allow their tissues to become free of bacterial contamination ("depuration"). This process adds considerably to the cost of production and it is therefore unlikely that this industry will experience any expansion in Pender Harbour in the near future.

No other aquacultural operation is located within Pender Harbour although there are a number of salmon farms in nearby Agamemnon Channel. Of these farms, Saga Seafarms Ltd. is the closest to Pender Harbour (Fig. 4). Located at Daniel Point, this salmon farm is not within the designated study area, but is close enough to be impacted should the water quality in Pender Harbour deteriorate significantly. Conversely, it is unlikely that effluent derived from this farm (fish food and faeces) exerts a measurable influence on the water quality of Pender Harbour, since salmon farm impacts appear to be largely localized (Cross, 1990).

At least two clam harvesting areas are also located near the study area. E.P.S. (1991) has identified two beaches south of Bargain Bay that are subject to harvesting (Fig. 4). As with the salmon farm, it is possible that a substantial deterioration in water quality in Pender Harbour could adversely affect this resource.

Figure 4. Aquaculture Resources in the Pender Harbour Area


North
Daniel Pt.
Hotel Lake
Garden Bay Lake
Irvines Landing
Garden Bay
Oyster Bay
Donnely Landing
Gunboat Bay
East Bay
Madeira Park
Francis Peninsula
Paq Lake
Bargain Bay
MALASPINA STRAIT
Salmon farm
Area closed to shellfish harvesting
Clam harvesting areas
Oyster lease
0
1
2 km

4. WASTE DISCHARGES

4.1 POINT SOURCES

There are few permitted effluent discharges directly into Pender Harbour as most liquid waste is disposed via discharge to ground (tile fields). Only three permits are currently in effect which authorize discharge into the harbour. These permits have been issued to the Sundowner Inn (PE-4728), the Pender Harbour Fishing Company Ltd. (PE-7555), and John Henry's Marinas Inc (PE-8384) (Fig. 5). Immediately south of Bargain Bay and just outside the designated study area are two additional permitted discharges. These permits have been issued to Helen Cates (PE-7706) and the "Owners of Strata Plan VR 270" (PE-4186) . The former is a private residence on a small island (Cates Island) and the latter is a residential complex adjacent to the Sunshine Coast Highway. Although neither of these effluent sources are in the designated study area, the waters to which the effluent is discharged are immediately adjacent to Bargain Bay and a review of their potential impacts is considered appropriate to this study.

The dilution and distribution of effluent once discharged at depth in marine waters is determined by a number of physical characteristics. The most important of these are the velocity of discharge, ambient water current velocity, temperature/salinity differences between effluent and seawater, and ambient vertical temperature/salinity gradients (Nijman & Swain, 1990). These characteristics will determine the degree of available dilution as well as whether or not the effluent plume will reach the water surface. If the plume reaches equilibrium with ambient water conditions before it reaches the surface, then the plume is said to be "trapped."

In Pender Harbour, all discharges are low volume and the potential for dilution is substantial. During winter conditions when harbour waters should be relatively well mixed, a minimal vertical temperature gradient will enhance dilution. Conversely, in the summer the vertical temperature gradient (i.e., thermal stratification) in the harbour would tend to trap the effluent at a lower depth and minimize dilution. This could pose a potential problem if strong thermal barriers prevent tidal mixing from accessing and purging this deep water. Wastewater could then accumulate in these deep areas with little opportunity for dilution until such time as the water column became destabilized enough to permit mixing with upper water. On occasions when accumulated "trapped" wastewater is able to mix vertically (i.e., during thermal destabilization), surface waters in the harbour could potentially experience high levels of nutrient enrichment or other types of pollution. Further temperature/salinity profile data must be collected from the harbour to ascertain whether or not such a scenario is actually possible in Pender Harbour.

4.1.1 The Sundowner Inn (PE-4728)

The Sundowner Inn is an older resort hotel overlooking Hospital Bay and immediately above the Hospital Bay Government Wharf. The inn is in operation from March to September and consists of 16 units (Accommodations, 1990). Effluent from the Inn is processed through a secondary treatment plant located in front of the building and is then discharged through a marine outfall. The outfall extends approximately 762 m west southwest and discharges at a depth of 21 m below low water level, near the centre of the main basin of the harbour (Fig. 5). The maximum permitted discharge through this outfall is 10 m^3/day. Obviously this discharge would be reduced during the winter off-season.

The Permittee is required to obtain grab samples of the effluent twice per year during the operating period and to analyze the samples for 5-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS). Effluent quality is required to be equivalent to or better than 45 mg/L BOD_5 and 60 mg/L TSS. In addition, the Permittee must monitor and record once a month the effluent volume discharged over a 24-hour period. Available data from this monitoring program are presented in Table 7.

Monitoring results indicate that although the permittee was occasionally out of compliance with respect to TSS and BOD_5 levels, flow rates were always well within the permitted maximum of 10 m^3/d. Note that flow rates are somewhat elevated during the summer months when tourist business is at its peak.

Applying the highest reported flow rate of 5 m^3/d to the mean reported values for suspended solids and BOD_5 (41.4 mg/L and 49.8 mg/L, respectively) yields a total daily load to the harbour of 207 g/d of TSS and 249 g/d of BOD_5. Although no measurements were obtained for effluent nutrient or bacteriological levels, these values can be estimated by applying "typical" effluent levels to the given flow rate. Typical septic tank effluent values as given by Canter and Knox (1985) were used to estimate loading to the harbour from PE-4728 to produce Table 8. These estimates are probably high as septic tank effluent is generally of a poorer quality than is secondarily treated sewage such as is being discharged at this site.

Figure 5. Permitted Waste Discharges in Pender Harbour

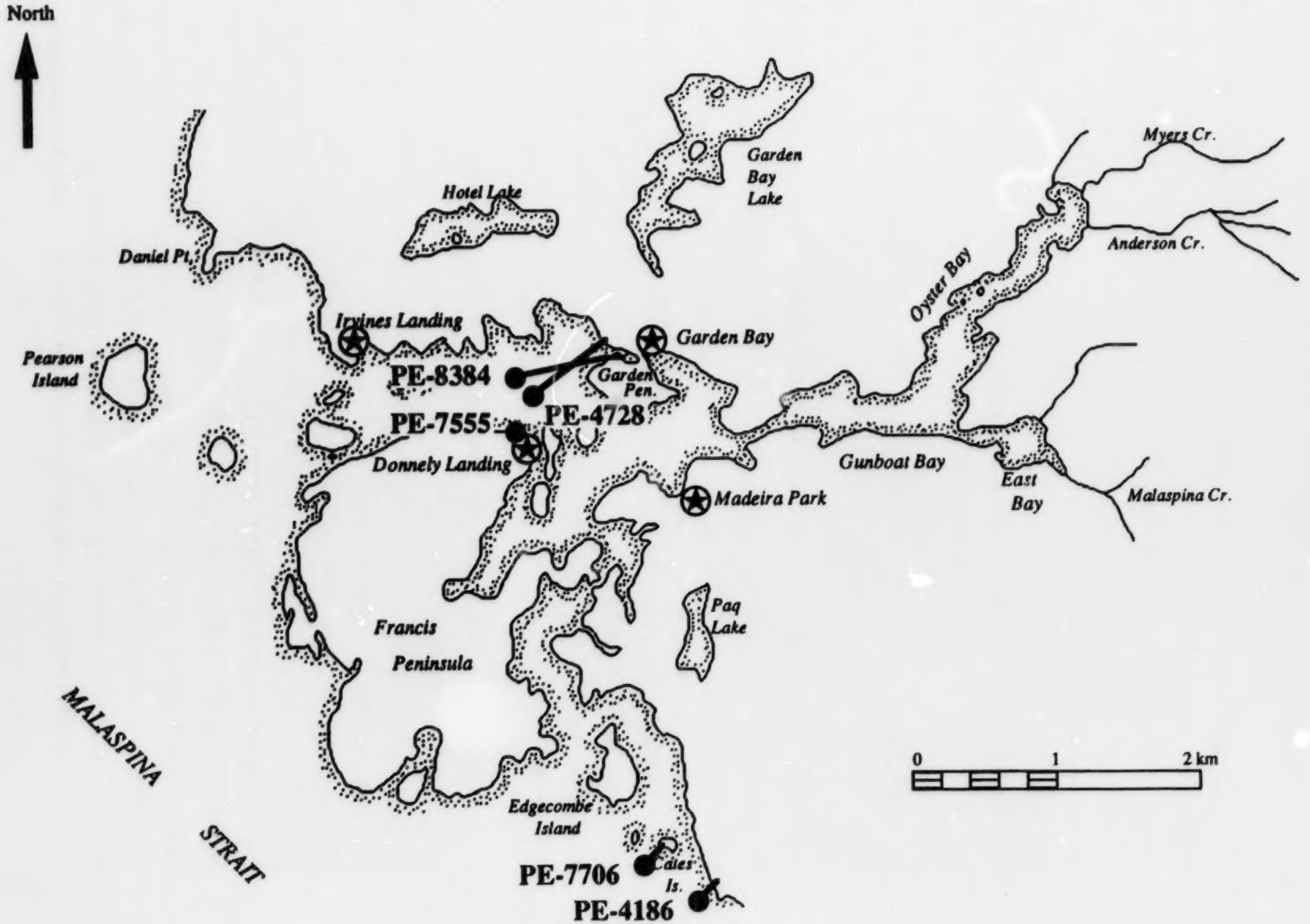

North
Hotel Lake
Garden
Bay
Lake
Myers Cr.
Anderson Cr.
Oyster Bay
Daniel Pt.
Irvines Landing
Garden Bay
Pearson
Island
PE-8384
Garden
Pen.
PE-7555
PE-4728
Donnely Landing
Gunboat Bay
East
Bay
Malaspina Cr.
Madeira Park
Paq
Lake
Francis
Peninsula
MALASPINA
STRAIT
0
1
2 km
Edgecombe
Island
Cales
Is.
PE-7706
PE-4186

Table 7. PE-4728 Monitoring Data

DATE	TOTAL SUSPENDED SOLIDS (mg/L)	5-DAY BOD (mg/L)	pH	FLOW (m^3/d)	SAMPLER
JAN 15/88				1.1	PERMITTEE
FEB 15/88				1.1	PERMITTEE
MAR 7/88	79.0	60.0	7.0		MOE
MAR 15/88				1.6	PERMITTEE
APR 15/88				1.6	PERMITTEE
MAY 2/88	45.5	63.0	6.8	2.1	PERMITTEE
JUN 15/88				1.6	PERMITTEE
JUL 15/88				1.6	PERMITTEE
AUG 15/88				3.7	PERMITTEE
SEP 15/88				3.2	PERMITTEE
OCT 31/88	9.0	30.0	7.0	2.6	PERMITTEE
MAY 1/89	41.5	31.1	6.9		PERMITTEE
JUN /89				3.5	PERMITTEE
JUL /89				4.2	PERMITTEE
AUG /89				4.9	PERMITTEE
SEP /89				5.0	PERMITTEE
OCT /89	32.0	65.0	6.9	2.8	PERMITTEE
MEAN	41.4	49.8	6.9	2.7	

Table 8. Estimated Daily Loading to Pender Harbour From PE-4728

CONTAMINANT	ESTIMATED CONCENTRATION IN EFFLUENT[a]	ESTIMATED DAILY LOAD TO HARBOUR	CONCENTRATION IN INITIAL DILUTION ZONE[b]
Suspended solids	41.4 mg/L	207 g	3.1×10^{-4} mg/L/d
5-Day BOD	49.8 mg/L	249 g	3.8×10^{-4} mg/L/d
Total Phosphorus	13 mg/L[a]	65 g	9.9×10^{-5} mg/L/d
Orthophosphorus	11 mg/L[a]	55 g	8.3×10^{-5} mg/L/d
Total Nitrogen	45 mg/L[a]	225 g	3.4×10^{-4} mg/L/d
Ammonia Nitrogen	31 mg/L[a]	155 g	2.4×10^{-4} mg/L/d
Nitrate Nitrogen	0.4 mg/L[a]	2 g	3.0×10^{-6} mg/L/d
Total Coliform	3.4×10^{6}/100 mL[a]	1.7×10^{11}	25.77/100 mL/d
Faecal Coliform	4.2×10^{5}/100 mL[a]	2.1×10^{10}	3.18/100 mL/d
Faecal Streptococci	3.8×10^{3}/100 mL[a]	1.9×10^{8}	0.03/100 mL/d

[a] ***Mean septic tank effluent concentration from Canter and Knox,1985.***

[b] ***Based on an initial dilution zone of radius 100 m and depth 21 m.***

If the maximum initial dilution zone for this effluent is defined as the body of water extending laterally 100 m in all directions from the point of discharge and vertically from bottom to water surface, then theoretical estimates of contaminant concentrations within this zone can be calculated (final column of Table 8). The volume of water available in this initial dilution zone is probably underestimated in these calculations since depth of water was considered to be 21 m, and this represents a low water measurement.

If the flushing rate for the harbour is assumed to be once per 3 days as calculated in Section 2 (summer conditions), then it must also be assumed that effluent contaminants can accumulate at three times the concentrations given in Table 8. Allowing for this 3-day residence time, all contaminants except the bacterial indicators would elevate ambient levels by amounts too small to be detectable by standard techniques. Any acceleration of the flushing rate as may occur during winter rainfall conditions would serve to further reduce accumulations.

Coliforms, however, may show small but significant increases within the initial dilution zone. If the daily elevation in concentration of faecal coliform is 3.18/100 mL (Table 8), then it can be assumed that overall accumulations during a 3-day residence time could be somewhat higher. The increase in concentration during this residence time may not be a completely linear response since *E. coli* do not survive long in marine water (Warrington, 1988), but it is apparent that a 3-day accumulation of this bacteria could approach the Canadian standard for shellfish growing waters of a median concentration of 14 per 100 mL. These standards require that growing waters suitable for harvesting bivalve molluscan shellfish (primarily oysters and clams) must have a faecal coliform median "most probable number" (MPN) of not more than 14/100 mL, and no more than 10% of the samples can exceed an MPN of 43/100 mL.

It should be noted that the above discussion pertains to the initial dilution zone only, which represents only a small portion of the total volume of the harbour. If the entire volume of the harbour is considered as the receiving water body for PE-4728, then available dilution for all contaminants, including microbiological indicators, would be such that any impacts would be indistinguishable from ambient water conditions. With the exception of possible localized coliform impacts, PE-4728 does not by itself constitute a serious threat to water quality.

4.1.2 The Pender Harbour Fishing Company Ltd. (PE-7555)

Tidal Wave Seafoods holds a discharge permit under the name of the Pender Harbour Fishing Company Ltd. Located at Donnely Landing at the north end of Francis Peninsula, this company is the only remaining waterfront fish processing plant in the harbour. Effluents discharged from this facility are washdown water and process effluent. A marine outfall immediately in front of the plant discharges the waste water close to shore at a depth of 4 m below low water. Before discharge, the waste water must pass through a 25 mesh screen (i.e., 0.7 mm openings) and discharge is permitted at a maximum rate of 3 m^3/d.

The terms of the permit require the Permittee to obtain grab samples of the effluent once per quarter for a period of one year. These samples are to be analyzed for 5-day BOD and TSS. Once per month 24-hour flow volume must also be obtained and these data are to be submitted along with the corresponding weight of fish processed during that period. The Permittee has had some difficulty in complying with these requirements because effluent discharge is so intermittent and of such low volume (Woodbine, pers. com., 1991). Operation of the plant is irregular and discharges, when they occur, are typically of short duration. For this reason, it is not expected that PE-7555 will contribute significant loading to the harbour and no attempt has been made to quantify the inputs. The shallow depth of the discharge and its position relatively close to the mouth of the harbour should ensure that tidal mixing and flushing will adequately disperse what little effluent is released.

4.1.3 John Henry's Marinas Inc. (PE-8384)

This permit is for a combined general store and marina operation located on the north end of Garden Peninsula. Effluent is discharged through a marine outfall extending 762 m from shore in a westerly direction and terminating at a reported depth of 21 m below low water level (Fig. 5). Secondary treatment of the effluent is required in a packaged treatment plant, and discharge is not to exceed 2.3 m^3/d. Five-day BOD_5 is to be maintained at 45 mg/L or better and total suspended solids must not exceed 60 mg/L under the terms of the permit. The Permittee is required to obtain a grab sample once every three months and analyze for these characteristics, as well as to measure and record once a month the amount of effluent discharged over a 24-hour period.

No data are available from this monitoring program at the present time, but estimates of loadings can be inferred based on a comparison with other effluent discharges. If it is assumed that effluent quality from this discharge is similar to that described for PE-4728 (section 4.1.1), then loadings can be calculated based on a daily flow rate of 2.3 m^3 (Table 9). Such calculations will probably tend to overestimate actual loadings since the flow rate of 2.3 m^3 represents the permitted maximum and actual flow rates are probably somewhat lower. Also, characteristics of the effluent are based mostly on values for septic tank effluent. Since discharge from John

Henry's undergoes secondary treatment, it is probably of a better quality, particularly with respect to BOD and suspended solids. The maximum initial dilution zone for this outfall is 100 m in all directions from the point of discharge and extending from surface to bottom. Using a discharge depth of 21 m, theoretical estimates of contaminant concentrations within this zone can be calculated (Table 9).

Daily loadings and initial dilution zone concentrations generated from John Henry's are almost exactly half of those calculated for the Sundowner Inn and the interpretation of impacts is therefore virtually identical. Levels of suspended solids, BOD, and nutrients are all so low as to be of no real consequence and only microbiological indicators reach significant concentrations within the initial dilution zone. The estimated faecal coliform level of 1.5/100 mL/d (Table 9) should be increased somewhat to allow for a predicted summer residence time of 3 days, but even allowing for this increase in concentration, levels should still remain below the Canadian standard for growing shellfish of a median MPN of 14/100 mL.

Table 9. Estimated Daily Loading to Pender Harbour From PE-8384

CONTAMINANT	ESTIMATED CONCENTRATION IN EFFLUENT[a]	ESTIMATED DAILY LOAD TO HARBOUR[b]	CONCENTRATION IN INITIAL DILUTION ZONE[c]
Suspended solids	41.4 mg/L	95 g	1.4×10^{-4} mg/L/d
5-Day BOD	49.8 mg/L	115 g	1.7×10^{-4} mg/L/d
Total Phosphorus	13 mg/L	30 g	4.6×10^{-5} mg/L/d
Orthophosphorus	11 mg/L	25 g	3.8×10^{-5} mg/L/d
Total Nitrogen	45 mg/L	104 g	1.6×10^{-4} mg/L/d
Ammonia Nitrogen	31 mg/L	71 g	1.1×10^{-4} mg/L/d
Nitrate Nitrogen	0.4 mg/L	1 g	1.4×10^{-6} mg/L/d
Total Coliform	3.4×10^{6}/100 mL	7.8×10^{10}	11.85/100 mL/d
Faecal Coliform	4.2×10^{5}/100 mL	9.7×10^{9}	1.46/100 mL/d
Faecal Streptococci	3.8×10^{3}/100 mL	8.7×10^{7}	0.01/100 mL/d

[a] *Using same values as determined for PE-4728*

[b] *Based on a flow rate of 2.3* m^3*/d*

[c] *Based on an initial dilution zone of radius 100 m and depth 21 m.*

The point of discharge for PE-8384 (John Henry's) is in the same vicinity as the point of discharge for PE-4728 (Sundowner Inn) and it is unclear if the initial dilution zones for these two outfalls overlap to some extent. If an area of overlap does occur, combined concentrations for most effluent constituents would not be elevated above ambient levels by detectable amounts. The exception to this are coliform levels which could closely approach or exceed the levels for shellfish growing waters within the area of overlap. Since most harvestable shellfish inhabit the intertidal zone rather than the deeper waters of the initial dilution zones, these slightly elevated coliform levels should not compromise this resource. Beyond the initial dilution zone, concentrations of all contaminants listed in Table 9 and originating from PE-8384 will decline to imperceptible amounts[1].

4.1.4 Helen K. Cates (PE-7706)

The discharge associated with this permit is domestic sewage from two residential houses on Cates Island, south of Bargain Bay. Although not directly within the designated study area, the permit authorizes discharge of effluent into marine waters near the southern entrance to Bargain Bay. For this reason, it is appropriate to review the details of the permit.

A 6 m^3 septic tank collects the wastes before discharging into Malaspina Strait through a submerged outfall extending approximately 250 m south southwest of the northwest tip of the island (Fig. 5). Depth of discharge is a minimum of 12.2 m. The rate of discharge is required to be no more than 3 m^3/d. No specific monitoring program has been required for this permit.

Discharge from this site is anticipated to be considerably less than the permitted maximum. Recent inspections by Waste Management staff indicate that there is currently only one residence on the island and that its use is infrequent (J. Van Haagstregt, pers. com., 1990). The permittee is a resident of North Vancouver and it is likely that the property is used primarily as a recreational retreat.

Mixing of the discharged effluent will be primarily tidal. At the time of permit application, a computer outplume simulation was performed to assess the effluent plume characteristics (H.E. Lai, 1987). This model predicted that at maximum permitted discharge, the outfall plume would ascend less than 2 m where it would reach a dilution of 250:1. This dilution would be achieved at a lateral distance of less than 1 m from the outfall. The small, irregular effluent volume, the large size of the receiving water body (Malaspina Strait), and the very rapid dilution at the point of discharge all suggest that this waste material will have no detectable impact on Bargain Bay or Pender Harbour water quality.

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[1] Public health inspectors have noted that the effluent line for PE-8384 frequently breaks below the marina and discharges directly into Hospital Bay. Such occurrences will result in near-shore bacterial impacts and it is essential that this problem be rectified.

4.1.5 Owners of Strata Plan V.R. 270 (PE-4186)

Permit PE-4186 belongs to a strata title residential complex 2.4 km south of Madeira Park (Fig. 5). As with PE-7706 (approximately 0.5 km to the northwest), this discharge falls outside the immediate study area, but is felt to be sufficiently close to Bargain Bay to warrant some consideration.

In 1975, a number of resort cabins were renovated and turned into permanent residential units on a waterfront lot adjacent to the Sunshine Coast Highway and just south of Edgecombe Island. A waste discharge permit has been issued to allow effluent discharge from this complex through an outfall extending approximately 52 m from low water mark into Malaspina Strait. Depth of water at the point of discharge is 15 m below low water level and maximum daily permitted discharge is 5.5 m^3. Effluent is treated in an activated sludge-type, batch treatment plant (secondary treatment) prior to discharge.

Terms of the permit require that effluent quality be maintained at equivalent or better than 45 mg/L BOD_5 and 60 mg/L TSS. The Permittee is required to sample the effluent each quarter to ensure that these objectives are maintained. Sampling consists of collecting grab samples from four consecutive batch discharges during normal operation of the treatment plant. The four samples are then combined into a single composite sample for subsequent analysis. A summary of analytical results submitted to date is presented in Table 10.

Table 10. PE-4186 Monitoring Data

DATE	TOTAL SUSPENDED SOLIDS (mg/L)	5-DAY BOD (mg/L)	pH	FLOW (m^3/d)	SAMPLER
FEB 89				2.0	PERMITTEE
MAR 89	75.5	54.0	7.2	1.7	PERMITTEE
APR 89				3.5	PERMITTEE
MAY 89				2.9	PERMITTEE
JUN 89	28.5	18.0	6.3	2.5	PERMITTEE
JUL 89				4.0	PERMITTEE
AUG 89				3.6	PERMITTEE
SEP 89	34.0	15.0	4.1	2.8	PERMITTEE
OCT 89				1.8	PERMITTEE
NOV 89				1.3	PERMITTEE
DEC 89	248.0	75	6.1		PERMITTEE
FEB 90				2.4	PERMITTEE
MEAN	96.5	40.5	5.9	2.6	

Table 10 shows that with respect to suspended solids and BOD_5, the discharged effluent from PE-4186 was only complying with permitted maximums 50% of the time. Flow rates however are consistently below the permitted rate of 5.5 m^3/d. Using the mean suspended solids and BOD concentrations and the maximum recorded flow rate of 4.0 m^3/d, estimated total daily loading and initial dilution zone concentrations of these constituents can be calculated. Nutrient (nitrogen and phosphorus) and coliform loads can also be approximated by using concentrations typical of similar effluent types. As was done for PE-4728 and PE-8384, typical septic tank effluent values (Canter & Knox, 1985) were used even though these probably overestimate actual effluent characteristics. The activated sludge-type secondary treatment used for this system should result in somewhat reduced nutrient and coliform levels as compared to septic tank effluent, although concentrations in both effluent types should remain in the same order of magnitude (Nagpal, pers. com., 1991).

The outfall for PE-4186 extends 52 m seaward, so an initial dilution zone of 25 m radius about the outfall terminus is appropriate to avoid impinging on the shoreline. Although such a restricted dilution zone is much smaller than the 100 m radius zones used for PE-4728 and PE-8384, concentrations of most effluent characteristics within the reduced zone are not increased by detectable amounts (Table 11). Increases in suspended solids and BOD_5 are well below detection limits, whereas some phosphorus and nitrogen species approach the detection limit, but remain below it. None of these characteristics are therefore expected to exert any significant impacts within the zone and influences outside the zone will be imperceptible.

Table 11. Estimated Daily Loading to Malaspina Strait From PE-4186

CONTAMINANT	ESTIMATED CONCENTRATION IN EFFLUENT[a]	ESTIMATED DAILY LOAD TO HARBOUR	CONCENTRATION IN INITIAL DILUTION ZONE[b]
Suspended solids	96.5 mg/L	386 g	0.013 mg/L/d
5-Day BOD	40.5 mg/L	162 g	0.006 mg/L/d
Total Phosphorus	13 mg/L[a]	52 g	0.0018 mg/L/d
Orthophosphorus	11 mg/L[a]	44 g	0.0015 mg/L/d
Total Nitrogen	45 mg/L[a]	180 g	0.0061 mg/L/d
Ammonia Nitrogen	31 mg/L[a]	124 g	0.0042 mg/L/d
Nitrate Nitrogen	0.4 mg/L[a]	2 g	6.8×10^{-5} mg/L/d
Total Coliform	3.4×10^{6}/100 mL[a]	1.4×10^{11}	475/100 mL/d
Faecal Coliform	4.2×10^{5}/100 mL[a]	1.7×10^{10}	58/100 mL/d
Faecal Streptococci	3.8×10^{3}/100 mL[a]	1.5×10^{8}	0.51/100 mL/d

[a] *Mean septic tank effluent concentration from Canter and Knox,1985.*

[b] *Based on an initial dilution zone of radius 25 m and depth 15 m.*

Microbiological indicators are predicted to be elevated in the initial dilution zone, with faecal coliform concentrations potentially surpassing the Canadian guidelines for shellfish growing waters. This estimate is based on the accumulated concentration occurring during a one day period of discharge, but in fact, the flushing rate for the area of discharge is expected to be significantly shorter than once per day. The outfall for PE-4186 discharges into the relatively exposed waters of Malaspina Strait and substantial water currents can be predicted due to the effects of tidal exchange, long-shore currents, and wind. These currents should substantially reduce concentrations of all effluent characteristics, including faecal coliforms, within the initial dilution zone. The concentration of faecal coliforms within the zone is therefore expected to approach the shellfish growing standard, and outside the zone all effluent characteristics should rapidly decrease to imperceptible levels. Since the outfall is located more than a kilometre south of Bargain Bay, no discernible impacts on the water quality of the Pender Harbour study area are anticipated.

4.1.6 Other Point Sources

Direct discharges of domestic sewage wastes into Pender Harbour have diminished over the years through public information and sanitary surveys. In 1978, 29 direct discharges from residences around the harbour were counted in a sanitary survey (Kwong & Weston, 1978). Many of these discharges have now been replaced with septic tanks and tile fields, however a few pipe discharges still remain (Walker, pers. com., 1989). Until another sanitary survey is conducted to quantify the number of direct discharges still remaining, it is not possible to calculate the effluent loading contributed to the harbour from these sources. A sanitary survey of Bargain Bay conducted in 1988 identified only one potential direct discharge into that body of water (Cavanaugh, 1988).

4.1.7 Implications of Restricted Water Circulation

Point source discharges are not expected by themselves to constitute a major impact on the water quality of Pender Harbour. Discharges in adjacent waters to the south of the study area (PE-7706 and PE-4186) were evaluated as being too small and too distant to exert any negative influence on the water quality of Pender Harbour. Illegal direct discharges from private residences around the harbour may cause some localized deterioration in water quality (particularly coliforms), but this source of input is steadily being eliminated and is difficult to quantify. The two major permitted sources in the harbour, the Sundowner Inn (PE-4728) and John Henry's (PE-8384), are small in volume with the only predicted impact being a slightly elevated coliform count in their respective initial dilution zones. This impact is confined to the initial dilution zones and should not compromise water quality in the harbour in general. It should be emphasized, however, that all calculations are based on estimates and assumptions, and that actual conditions could on occasion lead to levels of contamination exceeding those given here. Flushing rate in particular is susceptible to high variability and the three-day flushing rate used is a median value only. Tidal changes of low amplitude and, to a lesser extent, periods of low runoff, will serve to extend the flushing rate and result in higher concentrations of some characteristics. These events are expected to be relatively short-lived, and impacts are expected to be confined to initial dilution zones. Note that for all calculations, either the maximum recorded flow rate or the maximum permitted flow rate was used as a basis for effluent discharge. This was done to avoid underestimating effluent loading and to provide a counterbalance to flushing rates in excess of the median value used.

Estimates of loading from the Sundowner Inn (PE-4728) and John Henry's (PE-8384) are predicated on the assumption that vertical mixing of the water column occurs and that the entire volume of water in the harbour is regularly flushed. A strong possibility exists that water circulation is largely restricted to the upper waters of the harbour during the warm summer months when thermal stratification develops. The deeper water of the harbour, where these two outfalls discharge, may be isolated from surface waters by thermal barriers and isolated from outer water by the shallow sill at the mouth of the harbour. If the effluent plumes from PE-4728 and PE-8384 reach density equilibrium before escaping this zone, then their nutrient loads will continue to accumulate until stratification breaks down in the fall. Such accumulation could contribute to excessive nutrient, suspended solids, and BOD_5 levels within this confined water. The resulting high levels of nitrogen, depleted dissolved oxygen (D.O.), and sedimentation could alienate this portion of the water basin from finfish and shellfish populations. Both vertebrate and invertebrate mortalities have been documented during deepwater D.O. depletion in Howe Sound (Levings, 1980).

Entrapment and accumulation of effluent in the deep basin water could also affect surface waters. As thermal stratification breaks down in the fall, vertical mixing begins to occur and deep water starts to move towards the surface, bringing its accumulation of effluent constituents with it. This anoxic water could result in noxious odours and fish kills (Gade & Edwards, 1980). Surfacing nutrient loads during deep water renewal could also stimulate primary productivity, potentially contributing to phytoplankton "bloom" conditions with attendant deterioration of water clarity and aesthetics. Occasionally, blooms can be toxic to fish, and some constitute a health hazard to humans through bioaccumulation in bivalves (i.e., Paralytic Shellfish Poisoning and Diarrheic Shellfish Poisoning, or "P.S.P." and "D.S.P."). In addition, during senescence and subsequent decay, blooms can result in further oxygen depletion which can potentially drive D.O.

below the tolerance levels of some aquatic life forms. These events are likely to be infrequent and of short duration, but can nevertheless be biologically devastating if they occur.

There are currently insufficient data to determine whether or not effluent from PE-4728 and PE-8384 is subject to entrapment in the deep basin water such as is described above. A series of temperature/salinity profiles are required to establish the degree, depth, and timing of stratification, and water samples must be collected at depth to ascertain nutrient and D.O. concentrations (monitoring recommendations are described in detail in Section 6.4). In the absence of such data, an analysis based on the assumption that entrapment does occur is useful to see if nutrient-accumulation concerns are justified. The analysis must be interpreted with caution since both the depth of entrapment and the period of stratification are unknown.

Rapid vertical changes in water column temperature or density in a stratified water body can result in an effective barrier to vertical mixing. The depth at which these rapid changes occur is known as the "thermocline" in the case of temperature, or the "pycnocline" in the case of density. The pycnocline normally occurs at about the same depth as the thermocline since saltwater density is determined chiefly by water temperature and salinity. If a relatively stable thermocline or pycnocline exists in Pender Harbour, it is likely to occur at a depth of approximately 10 m. This is just slightly below the depth of the sill at the Skardon Islands near the mouth of the harbour. If it is assumed that water in the harbour basin below this depth is essentially trapped, then the volume of this confined water can be calculated by chart digitization as was done in Section 2.1. Using this method, the volume of water in Pender Harbour potentially trapped below a depth of 10 m was determined to be 7,650,000 m^3. Combining daily loads from PE-4728 and PE-8384 as given in Tables 8 and 9 results in daily loading to this trapped water of 302 g TSS, 364 g BOD_5, 95 g total phosphorus, 329 g total nitrogen, 226 g ammonia, and 3 g nitrate. Accumulation of bacteriological contaminants is not a concern because of the inability of coliforms to survive for extended periods of time in saltwater. If it is further assumed that a stable thermocline persists through the months of May, June, July, and August (123 days) and that all inputs are retained in the trapped water, then the net increase in contaminant levels can be calculated. The total increase in contaminant concentrations in the trapped deep water under these circumstances would be as follows: TSS - 0.005 mg/L, BOD_5 - 0.006 mg/L, total phosphorus - 0.002 mg/L, total nitrogen - 0.005 mg/L, ammonia - 0.004 mg/L, and nitrate - 0.00005 mg/L. None of these increases are within normal laboratory detection limits (Zenon Env. Labs., 1991) and do not constitute a significant threat to water quality in the harbour.

If it is assumed that the thermocline/pycnocline occurs at a depth of 20 m, then the receiving water volume is reduced to 1,100,000 m^3. A thermocline depth of 20 m must be considered unusually deep for local coastal waters, but is used here to provide a maximum range of trapped water volumes. If it is additionally assumed that the length of stratification is extended by one month, then contaminant concentrations increase by approximately a factor of ten over the above values: TSS - 0.042 mg/L, BOD_5 - 0.051 mg/L, total phosphorus - 0.013 mg/L, total nitrogen - 0.046 mg/L, ammonia - 0.031 mg/L, and nitrate - 0.0004 mg/L. None of these values represent levels of contaminants which would be considered toxic to marine life, but nutrient levels are high enough to have potential implications for productivity in the harbour. Possible inputs from other sources (i.e., illegal domestic pipe discharges) may further elevate contaminant levels.

In summary, it appears unlikely that effluent from permitted discharges in Pender Harbour will reach toxic concentrations in spite of possible accumulation due to entrapment. However, as the depth of the thermocline/pycnocline increases, the potential for nutrient concentrations to reach enrichment levels also increases. These increases may have some impact on productivity levels in the harbour during periods of destratification, but any such impacts are anticipated to be relatively minor and short-lived. Increases in the volume of effluent discharge reaching the deep water of the harbour, whether from increased discharge from existing permittees, new permits, or other sources, will necessitate a re-examination of the entrapment issue.

4.2 NON-POINT SOURCES

Non-point or diffuse sources of water pollution pose a more significant threat to the water quality of Pender Harbour than do existing identified point sources. The major non-point sources identified in this study are septic tank fields (domestic sewage), boating, and agriculture. Urban runoff and forestry also contribute some loading to the harbour.

4.2.1 Domestic Sewage

With very few exceptions, the homes and businesses surrounding Pender Harbour use septic tanks and tile fields to dispose of sewage wastes. Unfortunately, the steep angle of repose and the poor soil conditions of many areas around the harbour are not conducive to the optimum functioning of a tile field. Seepage from defective septic tank tile fields has been identified in a number of previous bacteriological surveys of the harbour and has been implicated as a contributing factor in the existing shellfish harvesting closures in effect today. A sanitary survey conducted in 1977 identified three particular problem areas in the harbour: South Hospital Bay -

North Garden Bay area, Welbourn Cove (Madeira Park), and Donnely Landing (Gough, 1977). In almost all cases, a steep shoreline and/or rocky bedding material are associated with problem discharges. A follow-up survey conducted in 1978 (Kwong & Weston, 1978) determined that, of the 336 waterfront houses surveyed, 52 homes (15%) had sewage disposal deficiencies. Of these 52 houses, 46 (88%) appeared to have inadequate area available for the installation of a full, conventionally-sized tile field.

Even where tile fields are not defective and are operating normally, it is likely that they still impact on the water quality of the harbour. Coarse soils typical of the area promote rapid nitrification of ammonia to nitrate. Very little of this nitrate is bound to the soil and in excess of 80% of it probably runs straight through the ground to be ultimately deposited in the harbour (Nagpal, pers. com., 1991). Under some circumstances, this additional nutrient load to the water could stimulate excessive primary productivity. During summer months when plankton productivity is generally high, nitrogen can become depleted in the water column. This results in "nutrient limitation" of the plankton population and productivity is held in check. Additional inputs of nitrogenous compounds can disturb this equilibrium and increase primary production. The nitrate discharged via septic tank effluent is readily bio-available to many plankton species and could induce such a reaction. The major initial consequence of elevated primary production is a deterioration of water clarity, but other effects may include blooms that are toxic to fish (*Chaetoceros* sp., *Heterosigma* sp.), blooms that cause toxicity in shellfish (P.S.P. or D.S.P.), or depletion of dissolved oxygen during senescence and decay of bloom phytoplankters.

Terrain classification maps of the Pender Harbour area (E.L.U.C. Secretariat, 1980) were examined by soils specialist Dr. N. Nagpal to evaluate the suitability of the specific soil types for septic tank drainfields. All terrain types bordering on the harbour were found to offer moderate to severe limitations to the renovation of septic tank effluents (Table 12). Almost all lands fronting on the main basin of the harbour were classified in the "severe limitation" category (Fig. 6). As this basin corresponds to the highest density of dwellings in the area, leaching of nutrients to the harbour is likely to be substantial.

Impacts from this nutrient-rich leachate should be mitigated to a large extent by the considerable capacity for dilution available in the harbour. To assess the scale of the impacts, it is useful to make some assumptions and provide an "order of magnitude" estimate of the expected increases in inorganic nitrogen levels in the harbour. There are approximately 400 lots along the shores of Pender Harbour so waterfront homes have not increased too dramatically in number from the 336 counted in 1977. Assume that there are currently about 375 waterfront homes around the

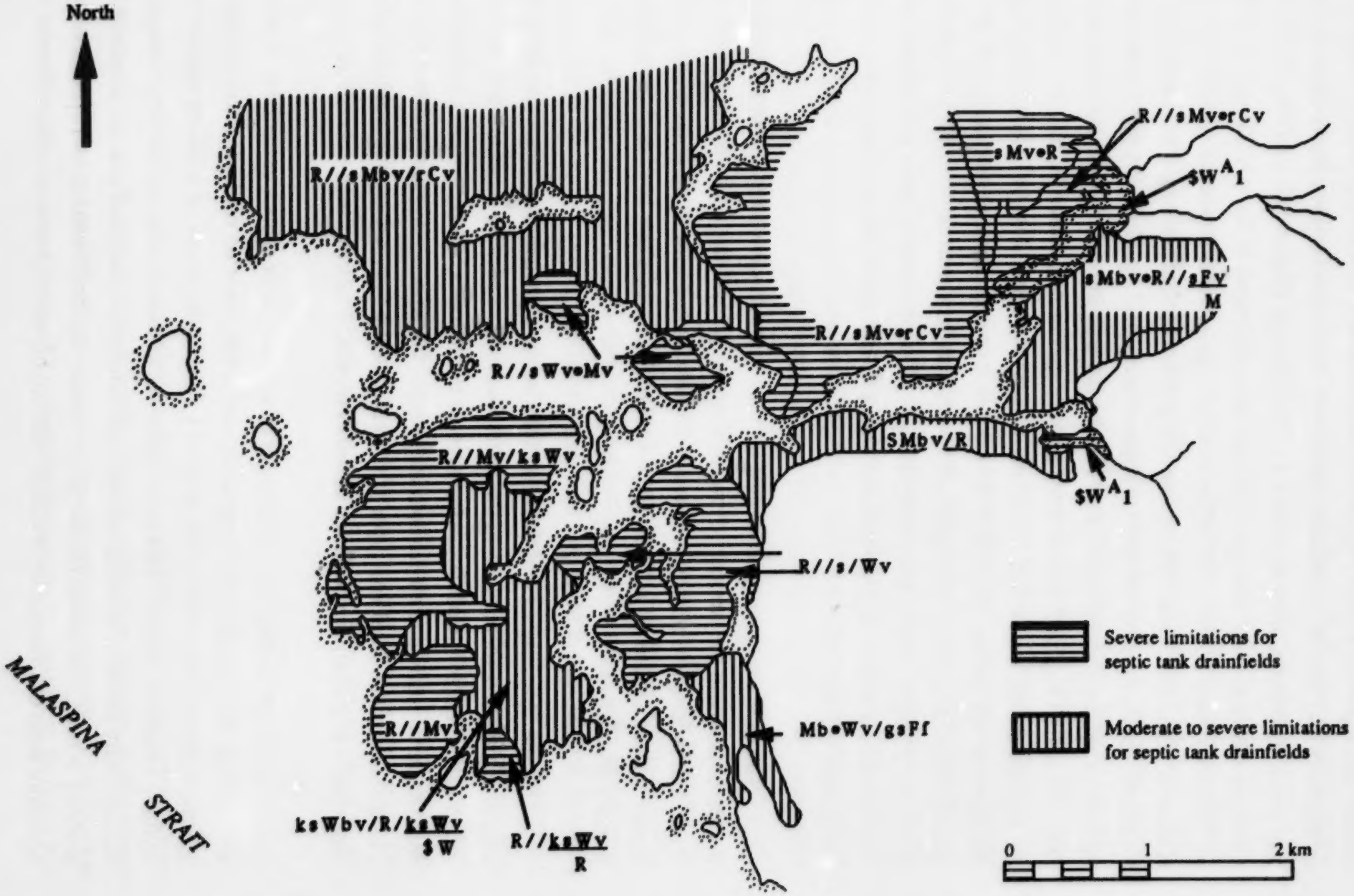
Table 12. Surficial Materials Characteristics and Their Suitability for Septic Tank Drainfields (STD)

Soil Type	Genetic material(s)	Texture	Depth	Limitations for STD	Comments
R//Mv/ksWv	bedrock outcrops and shallow soils predominate the unit; the rest is underlain by morainal till or to a lesser extent by marine deposits along the shoreline	cobbly sand (marine deposits)	0.1 to <1.0 m	severe	shallow to bedrock soils
R//Mv	predominantly bedrock outcrops and shallow soils; some morainal till deposits	-	0.1 to <1.0 m	severe	shallow to bedrock soils
ksWbv/R/$\frac{\text{ksWv}}{\text{sW}}$	marine deposits of varying thickness predominate the area; some shallow to bedrock soils	cobbly sand over silt (marine)	0.1 to >1.0 m	moderate to severe	moderately suitable areas highly permeable; leaching of nutrients to receiving waters possible
R//$\frac{\text{ksWv}}{\text{R}}$	bedrock outcrops and shallow soils predominate; some marine deposits	cobbly sand (marine)	0.1 to <1.0 m	severe	shallow to bedrock soils
R//sW	bedrock outcrops and shallow soils predominate; some marine deposits	sandy (marine)	0.1 to <1 m	severe	shallow to bedrock soils
Mb.Wv/gsFf	equal proportions of marine and morainal till deposits; some fluvial deposits	gravelly sand (fluvial fan)	0.1 to >1.0 m	moderate to severe	moderately suitable areas underlain by fairly permeable morainal till; leaching of nutrients to receiving waters possible
sMbv/R	predominantly morainal till deposits interspersed with shallow to bedrock soils	sandy (morainal till)	0.1 to >1.0 m	moderate to severe	shallow soils in areas of severe limitations; moderate areas very permeable; leaching of nutrients to receiving waters possible

Table 12 (cont.).. Surficial Materials Characteristics and Their Suitability for Septic Tank Drainfields (STD)

Soil Type	Genetic material(s)	Texture	Depth	Limitations for STD	Comments
sMbv.R//$\frac{\text{sFv}}{\text{M}}$	equal proportions of morainal till deposits, and bedrock outcrops & shallow soils with some fluvial deposits	sandy (morainal and fluvial deposits)	0.1 to >1.0 m	moderate to severe	moderately suitable areas highly permeable and vary in depth; leaching of nutrients to receiving waters possible
sW$^{\text{A}}$$_{\text{l}}$	marine	silty	not known	severe	evidence of active geological processes
sMv.R	equal proportions of morainal till deposits, and bedrock outcrop & shallow to bedrock soils	sandy (morainal till)	0.1 to <1.0 m	severe	shallow to bedrock soils
R//sMv.rCv	bedrock outcrops and shallow soils predominate; the rest of the area is underlain by morainal till and colluvial deposits	sandy (morainal till) to rubbly (colluvial)	0.1 to <1.0 m	severe	shallow to bedrock soils
R//sMbv/rCv	area underlain by bedrock outcrops and shallow soils predominate; some morainal till and colluvial (least of all) deposits	sandy (morainal till) to rubbly (colluvial)	0.1 to >1.0 m	severe to moderate	areas of moderate suitability in small proportion and highly permeable; possible leaching of nutrients to receiving waters
R//sWv.Mv	predominantly bedrock outcrops and shallow soils; equal proportions of marine and morainal till deposits in the rest of the unit	sandy (marine)	0.1 to <1.0 m	severe	shallow to bedrock soils

Figure 6. Terrain Classifications Around Pender Harbour and Suitability for Septic Tank Drainfields


North
R//sMbv/rCv
sMv•R
R//sMv•rCv
$W^A1
sMbv•R//sFv
M
R//sMv•rCv
R//sWv•Mv
SMbv/R
$W^A1
R//Mv/ksWv
R//s/Wv
R//Mv
Mb•Wv/gsFf
ksWbv/R/ksWv
$W
R//ksWv
R
MALASPINA
STRAIT
0
1
2 km

▤ Severe limitations for septic tank drainfields

▥ Moderate to severe limitations for septic tank drainfields harbour and that these homes provide the majority of the leachate reaching the water (some homes further back may also be contributing leachate). If it is also assumed that most of these homes are one or two bedrooms, then Appendix I of the Sewage Disposal Regulations of the Health Act specifies that the daily sewage flow can be anticipated to be a minimum of 250 imperial gallons/household (1136.5 L). If the total nitrogen concentration of that effluent is 45 mg/L (Cantor & Knox,1985) and 80% of that nitrogen reaches the harbour, then the total daily nitrogen load to the harbour can be estimated at approximately 15.3 kg. Since the mean water volume of the harbour is approximately 35,000,000 m^3, the increase in total nitrogen concentration should be about 4.4 x 10^{-4} mg/L/d. Allowing for a three-day flushing rate, total nitrogen concentrations in the harbour should not exceed 0.0013 mg/L above ambient. Most of this nitrogen is probably in the form of nitrate, but regardless of whether it is expressed as nitrate or total nitrogen, this concentration is an order of magnitude lower than the detection limit (D.L.) for either variable (D.L. = 0.02 mg/L, Zenon Env. Labs, 1991.). Nitrogen toxicity is not a factor at these very low concentrations and it is also unlikely that primary productivity would be impacted to any measurable extent.

The estimate of nitrogen loading is based on mean values and assumes complete mixing of the leachate within the harbour. Periods of extended low tides (low volume, low flushing), high input, and incomplete mixing may result in periods where localized areas experience somewhat higher concentrations of nitrate. Such events should be short-lived and have little impact on primary productivity.

Some leaching of coliform bacteria is also probable in many areas of the harbour supporting development close to the shoreline. Soils generally have a much better capacity to retain bacteria than nitrogenous compounds, but in areas of very shallow and permeable soils, some bacterial loading to the harbour may occur. Gerba *et al.* (1975) report that whereas bacterial movement through ideal soil types is normally only a few metres, transport through poorer soil types (such as gravel) can occur for distances up to 830 metres.

Although the bacterial component of the leachate is subject to the same extensive dilution available to the nitrogenous compounds, the initial injection of the leachate at the shore/water interface (the intertidal zone) can result in localized elevations of coliform concentrations in the shallow nearshore waters. This is the preferred habitat of oysters and many clam species and is consequently the area normally sampled for compliance with the Canadian standards for shellfish growing waters. Therefore, release of even relatively small amounts of coliform bacteria into the intertidal zone can frequently result in shellfish harvesting closures. All of Pender Harbour and

Bargain Bay are currently closed to the harvesting of shellfish. The relative contributions to this closure from tile field seepage, defective septic fields, boats, and direct discharges are difficult to assess.

In the absence of a trunk sewer line to serve the community, it is likely that continued population growth will result in increasing bacterial and nutrient loads to Pender Harbour. The population of the greater Pender Harbour area was 1286 in 1986 according to the most recent available census (Garden Bay - 349, Madeira Park - 326, Francis Peninsula - 441, Irvines Landing - 57, Kleindale - 113)(Stats Canada, 1988). Population growth in the entire Sunshine Coast area increased by an estimated 13% in the period 1981-1988 (Canadian Markets, 1989). Extrapolating from the 1986 census using that same growth rate would predict a 1991 population for Pender Harbour of 1405. Note that the summer resident population of the area is significantly higher than the census indicates. MacLaren Plansearch (1981) found that only 50% of the waterfront property owners in Pender Harbour gave Pender Harbour as their mailing address. Almost half (42%) were from Vancouver. Local tourist accommodation will also help swell the summertime population of the area. Ten resorts offer a total of 80 cottage or motel units and 145 campsites (Accommodations, 1990).

Most of the building construction associated with new growth in Pender Harbour has occurred inshore rather than on waterfront lots (judging from air photos). Since the likelihood of septic tank effluent impacting water quality diminishes with distance from shore, these homes pose a reduced threat to the harbour. This is particularly true with respect to bacteriological impacts, assuming that septic systems are properly installed and maintained. While much of the waterfront property in the main basin of the harbour is already occupied, considerable tracts are still unoccupied in the Gunboat Bay - Oyster Bay areas. Should this region be subject to intensive development, the water quality implications due to additional effluent loads could be substantial. To date much of this area is either undeveloped or used for agricultural purposes, but there has been some recent development activity on the south side of Gunboat Bay (Walker, pers. com., 1989)

4.2.2 Boats

The protected but accessible nature of Pender Harbour make this water body very attractive to boaters and has resulted in very high boating traffic. The 21 marina-type facilities in the harbour provide a combined moorage capacity of in excess of 750 boats which is typically 30% utilized in winter and 70% utilized in summer (Section 3.1). Additional moorage is available at the more than

200 small private floats and docks throughout the harbour as well as at a number of popular anchorages. This large number of boats in the relatively confined waters of Pender Harbour suggests that their combined impact on water quality is likely to be significant.

Boats can have a variety of effects on water quality including impacts due to sewage discharge, toxic antifoulant paints, fuel, oil, and exhaust emissions. Some of these problems are exacerbated by the fact that boats generally tend to moor in relatively shallow waters adjacent to shore. This means that the initial volume of water available for dilution of pollutants is nominal and localized impacts can occur. Sewage discharge from boats is probably the most serious of these impacts.

4.2.2.1 Sewage Discharge from Boats

Most of the sanitary and bacteriological surveys of Pender Harbour conducted to date implicate boats as a major source of bacterial contamination (Arney & Tevendale, 1974; Gough, 1977; Cavanaugh, 1988). Although the entire harbour is currently closed to the harvesting of shellfish due to bacteriological contamination, it is difficult to ascertain exactly how much of the problem stems from onshore sources (septic tank leachate) and how much originates from boats. However, boat discharges present a particularly potent problem. Faecal material contained in domestic (or municipal) sewage waste is generally combined with wash water, ground water, storm water, etc. before reaching the ocean and any soil through which the material passes will tend to retain bacteria. In contrast, discharges from boats contain fresh faecal matter that is concentrated, localized and viable (Kay, 1982). Such discharges obviously result in water fouling, but present a further problem in that normal water sampling techniques do not always detect such contamination because of the patchy but concentrated nature of the inputs. It has been suggested that bacteriological analysis of shellfish tissue may be a more satisfactory method for assessing actual contamination levels (Kay, 1982).

The amount of sewage discharged from boats in Pender Harbour is very difficult to ascertain. A large proportion of the vessels found in the harbour are small in size and not equipped with toilets ("heads"). Larger vessels generally possess a head, but may not have a holding tank as an alternative to direct discharge. Stringent U.S. regulations ensure that most American boats are equipped with holding tanks and U.S. vessels do constitute a significant proportion of the vessels visiting Pender Harbour (Table 5). The Canadian federal government is currently promulgating the Small Craft Sewage Pollution Prevention Regulations under the Canada Shipping Act which will require vessels in provincially "designated areas" to be equipped with holding tanks. Areas to be so designated are as yet unclear. Regardless of whether or not boats use holding tanks, Pender Harbour has very limited capability of handling the collected effluent. Only one marina currently possesses pump out facilities: the Seattle Yacht Club which services members only. Obviously better pump out services are required before holding tanks can offer an effective discharge alternative. Many marinas offer shore-based bathroom facilities for the use of their customers, but some residents feel there are currently inadequate public washroom facilities. Madeira Park Government Wharf, which is probably one of the busiest docks in the harbour, provides a portable toilet only during the summer months.

Vessels most likely to discharge sewage waste are "liveaboards" and larger transient vessels, including commercial fishboats. Liveaboards can be defined as semi-permanently moored boats serving as the principal residence of one or more people. A number of marinas in Pender Harbour regularly or occasionally accept liveaboards (Table 5). The number of such boats can be quite variable. Transient boats can find temporary moorage at only a few marinas and are probably most common at the government wharves, particularly Madeira Park and Hospital Bay wharves. These wharves are especially busy during the summer months and boats must often "raft" alongside each other due to shortage of dock space. Other transient vessels choose to anchor, with Garden Bay, Gerrans Bay, and the mouth of the harbour being preferred locations. Although washroom facilities are available at several marinas, some of the sewage waste from these vessels is probably directly discharged if holding tanks are not in place.

While the highly variable numbers and types of boats in Pender Harbour prevent any accurate estimate of the quantity of inputs, models exist which predict numbers of boats necessary to generate impacts. Tables reproduced by Kay (1982) relate area and mean depth to assimilative capacity such that shellfish growing water quality is not compromised. Using an area of approximately 3 km^2 and a mean depth of 10.5 m, the tables suggest that Pender Harbour should be able to handle 184 - 224 small boats without jeopardizing shellfish growing water quality. This of course assumes that there are no other sources of input aside from the boats. Kay reports a second model to calculate the number of boats allowable in an estuarine area such that faecal coliform concentrations remain below 14/100 mL. Using this model and allowing for both high and low tide volumes, 115 -181 boats would be the maximum permissible number of boats. Comparing the values obtained via either model with the substantially greater boat numbers (>500) using the harbour, it is clear that vessel discharges constitute a large component of the harbour's bacteriological loading.

Sewage wastes from boats can also be expected to contribute to the BOD_5, suspended sediment, and nitrogen loading of the harbour. It is not possible to quantify with any confidence the input of these characteristics since the number and status of polluting boats is so variable. However, using some very broad assumptions (as was done for septic tank drainfield leachate), it is possible to provide an "order of magnitude" estimate of input loads. The diffuse nature of the inputs (i.e., from multiple boats) prevents calculation of an initial dilution zone, so the diluting water body will be considered the harbour as a whole. Assume that during the summer, 525 or 70% of the 750 marina slips are occupied (Section 3.1). Further assume that there are an additional 150 boats at private docks and at anchor. Of the total of 675 boats, assume 20% or 135 of them are permanent or transient liveaboards and only 25% of these have holding tanks. This leaves a total of approximately 100 boats that are consistently discharging sewage wastes directly into the harbour. Nijman & Swain (1990) projected that effluent discharges from boats occur at a rate of 0.11 m^3/d and contain 250 mg/L concentrations each of BOD_5 and suspended solids, and 25 mg/L concentrations of ammonia nitrogen. The U.S. Environmental Protection Agency (E.P.A.) estimates that raw sewage has a total nitrogen load of 50 mg/L and an average faecal coliform concentration of 4×10^6/100 mL (E.P.A.[a], 1985). The results of applying these figures to the estimated 100 discharging boats are presented in Table 13.

Table 13. Estimated Daily Loading to Pender Harbour from 100 Boats

CONTAMINANT	ESTIMATED CONCENTRATION IN EFFLUENT	ESTIMATED DAILY LOAD TO HARBOUR	FINAL CONCENTRATION IN HARBOUR[a]
5-Day BOD	250 mg/L	2.75 kg	7.9×10^{-5} mg/L/d
Suspended Solids	250 mg/L	2.75 kg	7.9×10^{-5} mg/L/d
Ammonia Nitrogen	25 mg/L	0.28 kg	7.9×10^{-6} mg/L/d
Total Nitrogen	50 mg/L	0.55 kg	1.6×10^{-5} mg/L/d
Faecal Coliform	4×10^6/100 mL	4.4×10^{11}	1.3/100 mL

[a]Based on a mean harbour volume of 35,000,000 m^3

On a harbour-wide basis, the additional loads of BOD_5, suspended solids, and nitrogen derived from vessel discharges are negligible (Table 13). Even if the number of discharging boats were substantially higher than the 100 estimated, the increase in concentration of these characteristics would still be trivial. Concentrations would of course be much higher in the immediate areas of discharge (i.e., individual boats), but impacts from these characteristics are anticipated to be extremely localized and short-lived before dilution to background levels occurs. In contrast, faecal coliform concentrations predicted in Table 13 are high. Although the predicted overall concentration of 1.3/100 mL is still within the acceptable criteria for growing shellfish (14/100 mL), localized areas of discharge will experience much higher concentrations and will surpass criteria levels. Since most boats tend to moor or anchor in relatively shallow water, these areas of elevated concentrations will tend to conflict with existing shellfish populations which typically inhabit intertidal and adjacent waters. Such predictions are consistent with results obtained using predictive models described by Kay (1982) above.

4.2.2.2 Metals

Most vessels that are normally moored in marine waters are coated with antifouling paints designed to discourage the attachment and growth of algae and invertebrates. Until recently, the toxic agent in these paints has been either copper or tributyl tin (TBT). These biocides are slowly released either by leaching or sloughing and ultimately wind up in the water column and sediments. Boatyards where hulls are cleaned, sanded, or painted are also sources of these materials. TBT is a particularly potent chemical that can adversely impact mollusks at concentrations as low as one part per trillion (1 ng/L) (Champ & Pugh, 1987), and is known to bioconcentrate in fish and invertebrates. Recent regulations enacted under the federal Pest Control Products Act now prohibit the use of TBT on non-aluminum vessels of less than 25 m in length. While this will dramatically reduce the input of this chemical into the harbour, there are still boats coated with TBT paint that will continue to release TBT for several years (Crecelius *et al.*, 1990). Vessels exempted from the TBT regulations and non-complying vessels will continue to be a source of TBT to the harbour, but copper-based antifoulants are now the dominant antifouling paints. Aquatic organisms are known to be particularly sensitive to copper and the approved marine criteria for this metal has been accordingly set at 2-3 μg/L (Singleton, 1987). The E.P.A.^{b} (1985) found that the most sensitive marine animal species tested for acute toxicity to copper were embryos of the blue mussel and the Pacific oyster with LC50's of 5.8 and 7.8 μg/L respectively. Chronic toxicity and sublethal effects occur at even lower concentrations. In addition to its release from antifouling paint, copper is also released from corrosion of the copper, brass, and bronze fittings that are common on boats.

Champ and Bleil (1988) conservatively estimate that one quart of bottom paint containing 100 grams of copper and 50 grams of TBT will be used for each boat in a marina per year. Applying these figures to the estimated 675 boats using the harbour in the summer (Section 4.2.2.1) results in a total estimated annual load of 67.5 kg of copper and 33.8 kg of TBT. If it is assumed that these compounds are released into the water column at a steady rate, are well-mixed throughout the harbour, and are subject to a three day flushing time, then calculations show that concentrations would not reach problem levels. In fact, copper and TBT are released in greatest amounts around the busiest marinas (Madeira Park and Hospital Bay areas), and it has been demonstrated that these chemicals can accumulate to elevated levels in the sediments below such operations (Crecelius *et al.*, 1990). No current data are available on concentrations of TBT or copper in either the water column or the sediments of Pender Harbour.

Other heavy metal contaminants associated with boats include lead and zinc. Lead is a commonly used ballasting material and, until recently, was a fuel additive. Zinc is common in the galvanized material used on boats and is routinely used as sacrificial anodes. Both lead and zinc were found to exist at elevated concentrations in the sediments below two marinas studied by Crecelius *et al.* (1990) in Washington State. Concentrations of both metals in marina sediments were higher by a factor of 2 to 5 compared to sediments of similar characteristics located outside the marinas. No data for these metals are available for Pender Harbour.

4.2.2.3 Petroleum Products

The fossil fuels and related combustion products associated with boat engines result in several inputs to the water including oily bilge discharges, minor fuel spills, and exhaust emissions. The high number of boats using Pender Harbour combined with the confined nature of the harbour raise concerns that some of these inputs may result in significant impacts on water quality. Bilge discharges and minor fuel spills provide the most readily visible of these impacts, and are often mentioned by local residents when asked to comment on local water quality. Such incidents are not uncommon around refuelling docks and marinas, but the resulting slicks are normally small and quickly dispersed. They are typically regarded as nuisance conditions that are objectionable primarily due to visual impacts and smell. These sorts of impacts are preventable through the use of proper refuelling and maintenance practices by the boating public.

Pender Harbour is also vulnerable to more extensive fuel spills should a catastrophic leak develop at either of its two commercial fuel docks (Irvines Landing and Hospital Bay). Normal safety and construction standards are presumably observed at both facilities to minimize the chances of such an occurrence, but other private operations may not be operating to the same standards. At least one boat rental company was observed to have fuel lines running from an onshore depot to its boat docks, and these installations had reportedly not been subject to inspection by proper authorities. An unchecked fuel spill due to a damaged main fuel line would likely result in extensive environmental damage.

Spills or persistent leaks of fuel such as may occur around fuel docks and marinas are a potential source of polycyclic aromatic hydrocarbon (PAH) loading to the sediments. These toxic compounds are readily sorbed onto suspended particulates and biota (EPA, 1980) and will tend to sink to the bottom and accumulate. A study in Washington State has implicated marinas as a source of elevated concentrations of PAH in the underlying sediments (Crecelius *et al.*, 1990). No data for this contaminant are available for Pender Harbour.

While most exhaust emissions escape to the atmosphere, exhausts that are discharged below the water line (which includes most outboard engines) result in condensation of some constituents into the water column (Butcher, 1982). This mechanism provides an additional loading of hydrocarbons to the water column and sediments. Condensates of small amounts of carbon dioxide and carbon monoxide are also released through exhaust emissions. These compounds are expected to be quickly assimilated into the ocean carbon budget with virtually no impact.

4.2.3 Agriculture

Whereas septic wastes and boating inputs are the dominant impacts in the main basin of Pender Harbour and Bargain Bay, agriculture is probably the primary source of impacts in Gunboat Bay, Oyster Bay, and East Bay. Much of the upland surrounding both Oyster Bay and East Bay is farmland (Kay *et al*, 1982), and both bays have freshwater streams draining into them that pass through grazing lands. Bacteriological analysis of these streams in 1974 (Arney & Tevendale), 1977 (Gough), 1978 (Kwong & Weston) and 1982 (Kay *et al.*) consistently showed excessive coliform concentrations with upstream livestock generally being implicated as the main source of the problem. This contamination is reflected in the marine waters of the bays which have been closed to the harvesting of shellfish since 1964 (Arney & Tevendale, 1974).

At the north end of Oyster Bay, Anderson Creek and Myers Creek drain an area that includes several kinds of agricultural enterprises. Although a piggery along Anderson Creek noted in the 1977 study is no longer in existence, a small hobby farm continues to operate along the banks of Myers Creek near its discharge into the bay. This farm reportedly supports approximately 20-25 head of horses and cattle as well as some chickens (Walker, pers. com., 1989). Drainage from this property, particularly during periods of rainfall, can be expected to contribute significant bacterial and nutrient loading to the bay. More information is required before it would be possible to attempt to quantify the inputs from this source.

More intensive agriculture is practiced at an extensive greenhouse facility located between the two creek systems. The greenhouses employ a hydroponic system from which excess leachate is normally collected into a large holding tank. During summer, this leachate is sterilized and used to irrigate crops. In winter, however, feeding of plants is much reduced and, when the holding tank is full, excess leachate is allowed to overflow into the nearby fields. These fields are adjacent to the mudflats at the head of the bay and are bounded by the streams, so much of this nutrient-rich leachate likely runs directly into the bay. The effluent should not, however, be a direct source of faecal contamination.

A third operation in the same vicinity should more properly be classified as aquacultural rather than agricultural. The Anderson Creek Salmon Hatchery is a small operation consisting of only a few above ground fish rearing tanks and troughs. Effluent is discharged through a rock filter and settling pond and finally into a ditch which empties into the marshy area at the head of Oyster Bay. The operation is licensed (#65260) to use water from Anderson Creek at the rate of 2.5 ft^3/s, but during a site inspection in 1990, only one tank was in operation and flow-through was almost nonexistent. The effluent treatment arrangements should be reasonably effective at removing particulates and, since fish are not a source of coliform contamination, the main water quality impact from the hatchery is expected to be nutrient enrichment. The concentrations of nitrogen and phosphorus in the effluent will vary depending on the number and size of fish being stocked and their feeding rates, but the very low flows suggest that actual impacts on the receiving waters (Oyster Bay) will be minimal.

South of Oyster Bay, East Bay also receives two small streams that drain agricultural uplands (Fig. 2). While numbers of livestock grazing in these areas appear to be relatively low, the creeks have consistently showed elevated coliform levels. Some of this contamination may be originating from non-agricultural sources, however. The 1978 study (Kwong & Weston) showed faecal contamination of the southernmost stream (sometimes referred to as "Malaspina Creek") upstream from a small ranching operation. They suggested that the major source of contamination for this stream may originate in the vicinity of a gravel pit further upstream. Regardless of the source, coliform levels in East Bay have been found unsuitable for growing shellfish.

In both Oyster Bay and East Bay, Kwong and Weston also collected and compared bacteriological data from rainy days and dry days. They concluded that landwash has a significant effect on bacterial contamination levels in these areas. At stations directly downstream from locations with concentrations of domestic animals and people, coliform levels were distinctly elevated when measured during or immediately after periods of rainfall. These areas of high input correspond to areas where natural vegetation has been removed for farming, homesites, and roads and thus result in direct runoff to the creeks (Kwong & Weston, 1978). After several days of sustained rainfall, elevated coliform concentrations tend to subside to normal levels as accumulated wastes are flushed from the land. Elevated contamination levels during rainfall events are also consistent with the previous analysis of landforms surrounding the harbour (Table 12, Fig. 6). Soils throughout the harbour area have been characterized as shallow with only limited ability to retain or renovate waste discharges. Rainfall would therefore be expected to accelerate the movement of ground contaminants towards the harbour.

Although landwash is expected to have the most pronounced effect in Oyster Bay and East Bay because of the presence of livestock, the more heavily populated main basin will also experience increases during wet periods. Roofs, lawns, and paved surfaces shed accumulated wastes (bird and pet faeces) much more rapidly than would natural surfaces. In addition, runoff will accelerate the movement of septic effluent through the ground to the harbour. These events represent a flushing of accumulated wastes rather than a steady, continuous input and can therefore be expected to be short in duration. Increased volumes of freshwater flowing into the sea should also help to increase the flushing rate of the harbour (Section 2.2), thus helping to mitigate the effects of landwash.

4.2.4 Forestry

Logging clearcuts were noted on the hillsides in the immediate vicinity of East Bay during a site visit in 1990. Such activities may result in increased nutrient and sediment loads to the harbour, however, these increases are expected to be largely confined to the rainy winter months. Primary productivity in Pender Harbour is normally light-limited during the winter months, so additional nutrient inputs during this season are not expected to have notable impacts. Particulate loading due to logging practices probably occurs to some extent, but the presence of an active oyster lease in Oyster Bay suggests that sedimentation is not occurring to a pronounced extent. Heavy sedimentation would tend to smother young oysters and make the area unsuitable for oyster culture. Any influence on water quality due to sediment loading is therefore predicted to be largely confined to the aesthetic impacts associated with a reduction in water clarity.

5. WATER QUALITY

5.1 BACTERIOLOGY

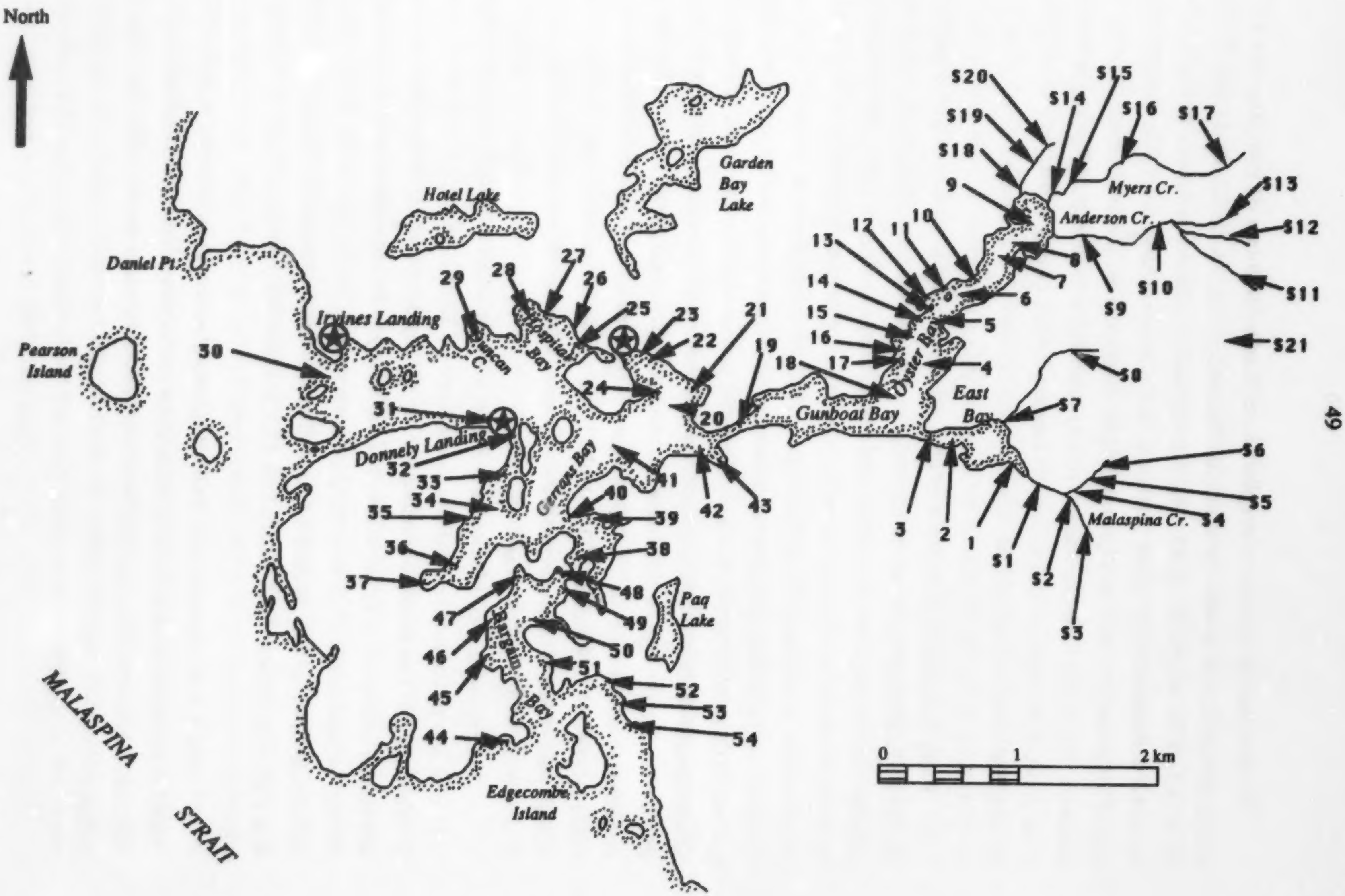
Several water quality studies have been conducted in Pender Harbour, but all have concentrated solely on bacteriological/sanitation concerns and were initiated in response to recreational and commercial shellfish harvesting activities in the area. Consequently, available water quality data for the harbour are confined almost exclusively to bacterial analysis of surface waters with associated temperature and salinity measurements. The results of these studies have led to progressively expanding shellfish closures in the harbour (Fig. 4).

In 1964, personnel from the federal Department of Fisheries and National Health and Welfare and from the provincial Department of Health and Hospital Insurance surveyed the water quality in Pender Harbour. Based on the results of that study, the commercial oyster leases operating in Oyster Bay were closed to shellfish harvesting due to unacceptable bacterial contamination of the water. A subsequent survey by the Department of Health and Hospital Insurance in 1967 confirmed the earlier closure and closed all shellfish harvesting east of the overhead power lines marking the entrance to Gunboat Bay (Arney & Tevendale, 1974). Data from these studies were not available for this report.

A sanitary survey was again conducted in Pender Harbour in July 1974, this time by the Environmental Protection Service (E.P.S.). The survey was initiated because expanding development and increasing recreational boating in the area were perceived as a threat to shellfish growing water standards. These standards were based on the U.S. Food and Drug Administration's National Shellfish Sanitation Program. Shellfish growing water bacteriological criteria under this program were defined as follows:

> In order that an area can be considered bacteriologically safe for the harvesting of shellfish, the total confirmed coliform median Most Probable Number (MPN) of the water must not exceed 70 per 100 mL, and not more than 10 percent of the samples ordinarily exceed an MPN of 230 per 100 mL for a 5-tube decimal test in those portions of the area most probably exposed to faecal contamination during the most unfavourable hydrographic and pollution conditions (Arney & Tevendale, 1974).

Figure 7. Bacteriological Sampling Stations in Pender Harbour


North
Pearson Island
Daniel Pt.
Irvines Landing
Hotel Lake
Garden Bay Lake
Duncan C.
Hospital Bay
Donnely Landing
Gerrans Bay
Gunboat Bay
Oyster Bay
East Bay
Myers Cr.
Anderson Cr.
Malaspina Cr.
Paq Lake
Bargain Bay
Edgecombe Island
MALASPINA STRAIT
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Twenty marine sites were sampled in the Pender Harbour - Bargain Bay area and one stream entering East Bay was also sampled (stations 2, 5, 18, 19, 20, 22, 26, 27, 30, 33, 35, 37, 38, 41, 43, 44, 45, 48, 52, 53, & S2 - Fig. 7 & Appendix I). Based on the total coliform criterion described, stations in Gunboat Bay (stations 2, 5, & 18), Garden Bay (20 & 22), Hospital Bay (26 and 27), Gerrans Bay (35 & 37), and Bargain Narrows (38), failed to meet growing water standards. The shellfish closure was accordingly expanded to include all of Pender Harbour inside a line drawn from Duncan Cove to Donnely Landing. Water quality in Bargain Bay was found to be acceptable for growing shellfish.

Faecal coliform data from the 1974 study indicate that at no time did concentrations at marine stations exceed the current primary-contact recreation criterion. This criterion states that for primary-contact recreation (including swimming, diving, wading, SCUBA, windsurfing, water skiing, etc.) faecal coliform levels should not exceed a geometric mean of 200/100 mL in 5 samples taken in a 30-day period (Warrington, 1988). Only the freshwater station on Malaspina Creek (S2) failed to meet this criterion. The Malaspina Creek station had a geometric mean faecal concentration of 500/100 mL, probably due to the presence of livestock in the drainage area. It should be noted that at the time this study was conducted, an additional recreational criterion was in effect. The Health Branch "standards for bathing, swimming, recreation" specified not only a maximum geometric mean of 200/100 mL, but also required that not more than 10% of the samples could exceed an MPN limit of 400/100 mL. Under this additional restriction, marine station 2 in East Bay also failed to meet acceptable bacteriological levels for recreational purposes.

The expanded shellfish closure in Pender Harbour heightened local concerns about water pollution and prompted the Sunshine Coast Regional District to request a survey to pinpoint pollution inputs. This survey was undertaken in 1977 by the provincial ministries of Environment and Health, and involved a door to door sanitary survey as well as water quality sampling (Gough, 1977). Fifteen marine sites were sampled (stations 3, 4, 19, 21, 23, 25, 28, 29, 31, 32, 34, 36, 40, 42, & 50 - Fig. 7 & Appendix I) as well as five freshwater sites in the streams entering the east end of the harbour (stations S5, S10, S13, S16, & S17).

New E.P.S. standards for shellfish growing waters in accordance with the Canadian Shellfish Sanitation Program were in effect at the time of this study. These standards assess faecal coliform levels rather than total coliform levels as was formerly the case. The new criteria are as follows:

> In order that an area be considered bacteriologically safe for the harvesting of shellfish, the faecal coliform median MPN of the water must not exceed 14 per 100 mL, and not more than 10% of the samples ordinarily exceed an MPN of 43 per 100 mL, in those portions of the area most probably exposed to faecal contamination during the most unfavorable hydrographic and pollution conditions (Kay *et al*, 1982).

Based on these criteria, only marine stations 23 and 25 (Garden Bay and Hospital Bay respectively) were found to have water quality unacceptable for harvesting shellfish (Appendix I), and all marine stations were within acceptable limits for primary-contact recreation. This constitutes an apparent improvement in water quality from the 1974 study, but Gough attributes the decrease in coliform levels to excessive transit time of the samples and "drier less bacteriologically engendering conditions" at the time of sampling rather than to any fundamental improvement in water quality. In contrast, freshwater stations S5, S10, S13, and S16 all exceeded median faecal coliform levels of 14/100 mL and therefore had potential to contaminate shellfish growing areas in the Gunboat Bay area. All freshwater stations except S10 (lower Anderson Creek) met the current provincial criteria for primary-contact recreation of a geometric mean faecal coliform level of not more than 200/100 mL. Three additional stream sites (S5, S13 & S16) failed to meet the second recreational criterion in effect at the time (i.e., not more than 10% of the samples to exceed an MPN of 400/100 mL). Under this additional criterion, only station S17 was found to have acceptable water quality for recreational purposes. Regardless of the criteria used, all the streams are quite small and shallow and it is unlikely that they are routinely used for swimming, bathing, or wading.

A followup to the 1977 study was conducted by the Coast Garibaldi Health Unit during the summer and fall of 1978 (Kwong & Weston, 1978). This study attempted to recommend possible solutions to site-specific septic tank and tile field problems and to try and track down creek contamination sources. Sixteen stations on the creeks emptying into Oyster Bay and East Bay were sampled during this survey (stations S1, S3, S4, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, & S19 - Fig. 7) and all showed varying levels of faecal contamination (Appendix I). Median values at these stations ranged from a low of less than three at station S3 to a high of 152 at station S19. Eleven out of the sixteen stations had the potential to adversely impact shellfish growing areas in Pender Harbour based on a median faecal coliform MPN of in excess of 14/100 mL. Using current primary-contact recreation criteria, all stream sites had acceptable coliform concentrations, although six sites failed to meet the second criterion in use at the time. No marine water quality analysis was conducted during this study.

Due to the presence of active oyster leases in Oyster Bay, the Environmental Protection Service again re-surveyed the streams and marine waters of the Gunboat Bay area in February and August/September of 1981 (Kay *et al*, 1982). Twelve marine stations were sampled (stations 1, 3, 6, 8, 9, 10, 11, 12, 13, 15, 16, & 17 - Fig. 7) and twelve freshwater sites were also tested (stations S1, S3, S6, S7, S10, S11, S13, S14, S17, S18, S20, & S21 - Fig. 7). With only two exceptions (station 10 in Aug/Sept and station 15 in Feb), all marine stations failed to meet the shellfish growing water criteria (Appendix I). Grouping all the MPN data from the summer period resulted in a combined median of 9.5/100 mL and a 90th percentile of 79/100 mL. Based on these results, the shellfish closure in effect for Gunboat Bay was maintained. Oysters grown on the commercial leases in the bay must therefore continue to be relayed to an approved area and allowed to depurate before they are suitable for human consumption. All freshwater stream stations sampled showed evidence of faecal contamination. Inadequate replication at these stations prevents calculation of meaningful median values, but faecal coliform levels ranged from 0 to 3000/100 mL and farm animals were implicated as the primary source.

The only marine station to exceed the primary-contact recreation criterion of 200/100 mL was station 9 right at the head of Oyster Bay (Fig. 7). This station is in the high intertidal zone of the bay, and is probably more representative of the combined discharges of Anderson and Myers Creeks than of the bay at large. This is reflected by the very low salinities recorded for this station (3.5 - 8.0 ppt). Insufficient replication was conducted to permit interpretation of freshwater coliform levels with respect to recreational use. All freshwater sites did, however, show some level of faecal coliform contamination.

The Coast-Garibaldi Health Unit of the provincial Ministry of Health has also conducted limited bacteriological sampling in the marine waters of Pender Harbour (Adams, pers. com., 1989). Sampling of this agency has been confined to beach samples on Garden Peninsula (station 24) and Gerrans Bay (station 39). Sampling conducted during August of 1987 and 1988 indicates that water quality at the Gerrans Bay station was inadequate for the growing of shellfish, while the Garden Peninsula station had acceptable water quality (Appendix I). Both stations were well within the recommended faecal coliform limits for primary-contact recreation.

The Environmental Protection Service again undertook a survey in the area during the summer of 1988. This survey was prompted by a positive test for *Salmonella* bacteria in a batch of shellfish originating from Bargain Bay (Cavanaugh, 1988). A sanitary survey of the shoreline was therefore conducted to identify potential sources of contamination. No water samples were collected and no quantitative data are available from this survey.

The sanitary survey located one straight pipe discharging from a home on the northeast side of Francis Peninsula and also noted heavy boating use in the area. The potential for contamination was considered substantial and the existing closure for Pender Harbour was consequently expanded to encompass all of Bargain Bay. The closure boundary is marked by the two prominent points of land at the south entrance to the bay, immediately northwest of Edgecombe Island. Cavanaugh recommended that additional survey work, including shellfish and sediment sampling, be conducted in Bargain Bay to locate actual sources of contamination.

The most recent bacteriological surveys of the area were conducted in October 1989, August 1990, and May 1991 by the Environmental Protection Service (E.P.S., 1991). Four stations were sampled in Oyster Bay (stations 7, 9, 12, & 14) and an additional seven stations were sampled in Bargain Bay (stations 45, 46, 47, 49, 51, 52, & 54) during all sample periods (Fig. 7 & Appendix I). E.P.S. has not yet evaluated the results from this study, but has kindly provided its data for the purposes of this report. Until such time as E.P.S. has analyzed its data, the shellfish closures previously described for Pender Harbour and Bargain Bay remain in effect.

During the October 1989 sample period, all marine stations in Oyster Bay exceeded the median faecal coliform criterion for shellfish growing waters of 14/100 mL. However, during the August 1990 sampling, these same stations all successfully met the criterion. This is consistent with the suspected agricultural sources of contamination which would be expected to contribute their maximum loads via landwash during the wet fall and winter months. Faecal material would tend to accumulate on land during the drier summer months with less opportunity to wash into the water courses. The May 1991 samples showed a moderate level of contamination consistent with a month of typically moderate rainfall. Station 14 showed acceptable water quality during this period whereas the other Oyster Bay stations exceeded the median faecal coliform criterion for shellfish growing waters by a small margin (i.e., 17-23/100 mL).

Bargain Bay showed no parallel contamination pattern. Six of the seven stations had acceptable shellfish growing water quality during all three sample periods. Only station 46 (on the west side of the bay) failed to meet the criterion and this occurred during both the October and August sample periods (results from the May 1991 samples at station 46 were below detection limits). These results suggest an isolated source of faecal input to the bay which may correspond to the straight pipe discharge noted in Cavanaugh's 1988 sanitary survey. Successful identification and remediation of this source may effectively prevent faecal coliform concentrations in Bargain Bay from exceeding shellfish growing water criteria.

Although all stations in Oyster Bay sampled during October showed elevated levels of faecal coliforms, only station 12 surpassed the primary-contact recreation criterion of a geometric mean of 200/100 mL. Sampling during the August and May periods showed significantly reduced levels at all stations and none exceeded the criterion. All sites sampled in Bargain Bay during both sample periods were well within the primary-contact recreation criterion.

All available bacteriological data from all agencies and years (Appendix I) were analyzed in an attempt to determine if overall faecal coliform concentrations are increasing or decreasing with time. Stations were grouped according to location and median faecal coliform data were lumped and examined using graphical and statistical techniques. Little discernible trend emerged from this analysis due principally to the high variability of the data (i.e., median faecal coliform concentrations ranged from a minimum of 1/100 mL to a maximum of 2300/100 mL, with a standard deviation of 236). A weakly-defined decline in faecal coliform median levels was noted in the Garden Bay / Hospital Bay area ($y = 42.68 - 0.466x$, $R^2=0.37$), but data for these stations (20-28) were sparse. Overall, the available historical data do not support a significantly increasing or decreasing tendency in marine coliform concentrations.

In general, the bacteriological water quality of Pender Harbour can be categorized by area:

i) Oyster Bay, East Bay, and Gunboat Bay can all be characterized as exceeding shellfish growing water criteria due primarily (probably) to the presence of livestock in the surrounding area. Infrequent, isolated incidences of coliform levels exceeding primary-contact recreation criteria may also occur in these waters. Coliform levels can be expected to increase during periods of high runoff.

ii) The main basin of the harbour including Gerrans Bay, Hospital Bay, and Garden Bay also has inadequate water quality with respect to growing shellfish, but the source of coliforms is likely to be largely human. This area supports much denser habitation with domestic sewage disposal and boating discharges contributing to bacterial loading. Swelling of the local population during tourist season is likely to exacerbate the problem but water quality in this basin continues to be adequate for primary-contact recreation.

iii) Bargain Bay is distinct from the above two areas in that it has less bacterial loading and is better flushed. Bacterial concentrations generally do not exceed shellfish growing water criteria (except in very specific areas), and no cases of coliform levels exceeding primary-contact recreation criteria have been documented.

Although Pender Harbour has been assessed by the Environmental Protection Service as having water quality unfit for harvesting shellfish, it is important to realize that bivalves are filter feeders that rapidly concentrate bacteriological contaminants in their digestive organs. Shellfish therefore require exceptionally clean water if they are for human consumption. A common perception around Pender Harbour is that shellfish closures imply substantial water pollution, but failure to meet shellfish growing criteria does not necessarily mean that water quality is severely compromised. The available data indicate only scattered incidences of Pender Harbour waters failing to meet primary-contact recreation criteria for faecal coliforms. These incidences are entirely confined to the Oyster Bay and East Bay areas and could likely be overcome by better agricultural practises in the vicinity. Farmers should be encouraged to maintain their stock at some distance from water courses, particularly during the rainy season.

The Federal-Provincial Working Group on Recreational Water Quality (1990) has prepared new draft guidelines to evaluate recreational water quality. The proposed indicator organism for primary-contact recreation in marine waters is enterococci, with a geometric mean not to exceed 350 per litre. The geometric mean is to be based on at least 5 samples taken during a period not to exceed 30 days, with re-sampling to occur if any individual sample exceeds 700 enterococci/L. No data are currently available to ascertain whether or not these criteria are being met in Pender Harbour.

5.2 OTHER WATER QUALITY CHARACTERISTICS

Whereas a wealth of historical bacteriological data are available for Pender Harbour, there is a distinct lack of all other kinds of water quality data. One Ministry of Environment site (EQUIS site number 0300143) was sampled on five occasions in 1978-79 at the approximate point of discharge of PE-4728 (Fig. 5). These data (Table 14) show most variables were within normal variability for inshore marine waters. Nutrient concentrations (nitrogen and phosphorous) do not indicate abnormal enrichment, although sub-surface phosphorous levels in May and August appear slightly elevated. These values may reflect sample collection immediately adjacent to the bottom sediments, where nutrient concentrations can be expected to be somewhat elevated. Phosphorous is seldom considered to be a limiting nutrient in coastal marine environments. Nitrogen levels suggest that sufficient nutrient was present to support productivity except during the summer months (May and August), when surface waters were depleted of nitrate. This is typical of normal productivity patterns in local marine waters. It is interesting to note that although nitrate values were at significant concentrations, levels of ammonia were very low. This is consistent with the

Table 14. Water Quality Data From Pender Harbour (EQUIS Site #0300143)

CHARACTERISTIC	SURFACE VALUES						SUB-SURFACE VALUES					
	Mar 21/78 (0 m)	May 17/78 (0 m)	Aug 17/78 (0 m)	Nov 1/78 (0 m)	Mar 14/79 (0 m)	Mean	Mar 21/78 (20 m)	May 17/78 (18.3 m)	Aug 17/78 (13.7 m)	Nov 1/78 (13.7 m)	Mar 14/79 (13.7 m)	Mean
Temperature (°C)	10.5	15.0	19.0	10.0	7.0	12.3	9.5	12.0	14.0	10.0	8.0	10.7
Spf. Cond. (µS/cm)	39200	35500	35800	44000	44200	39740	40500	43700	40800	42800	45800	42,720
pH	7.8	8.4	8.3	7.3	7.4	7.8	7.7	7.7	7.6	7.2	7.2	7.5
Diss. Oxygen (mg/L)	7.4	10.2	7.7	6.4	8.8	8.1	6.9	5.9	5.8	5.8	8.2	6.5
Secchi Depth (m)	6.7	4.3	4.3	11.0	10.7	7.4						
Total Ammonia (mg/L)	<0.01	<0.01	<0.01	0.03	<0.01	<.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01
Nitrate (mg/L)	0.30	<0.02	<0.02	0.29	0.36	0.20	0.35	0.31	0.28	0.24	0.40	0.32
Total Organic Nit. (mg/L)	<0.01	0.27	<0.01	0.02	0.02	0.07	<0.01	0.35	<0.01	0.03	<0.01	0.08
Total Kjeldahl Nit. (mg/L)	<0.01	0.27	<0.01		0.02	0.08	<0.01	0.35	<0.01		<0.01	0.10
Diss. Nitrite (mg/L)	0.007	<0.005	0.007	0.012	0.009	0.008	0.006	0.011	0.014	0.011	0.009	0.010
Diss. Nitrite+Nitrate (mg/L)	0.31	<0.02	<0.02	0.30	0.37	0.20	0.36	0.32	0.29	0.25	0.41	0.33
Diss. Ortho-Phos. (mg/L)	0.060	0.010	0.006	0.079	0.065	0.044	0.068	0.102	0.105	0.059	0.071	0.081
Diss. Total Phos. (mg/L)	0.065	0.018	0.026	0.088	0.072	0.054	0.076	0.109	0.146	0.068	0.077	0.095
Diss. Calcium (mg/L)			267	329	330	309			330	313	348	330
Diss. Silica (mg/L)	3.1					3.1	3.1					3.1
Diss. Magnesium (mg/L)		900	908	1210	1070	1022		1080	1120	1190	1100	1123
Diss. Sulphate (mg/L)	2153					2153	2153					2153
Diss. Chloride (mg/L)			12800	16000	30900	19900			16000	15300	32300	21,200
Diss. Hardness (mg/L)			4400	5800	5230	5143			5430	5680	5400	5503
Total Alkalinity (mg/L)		96.1	88.9	102.0	102.0	97.3		109.0	104.0	98.5	105.0	104.1
Total Chromium (mg/L)		<0.005				<0.005		0.013				0.013
Total Copper (mg/L)		0.002	<0.001	<0.001	<0.001	<0.001		0.002	0.003	<0.001	<0.001	0.002
Total Iron (mg/L)		0.012	0.016	0.019	0.027	0.019		0.500	0.183	0.055	0.047	0.196
Total Lead (mg/L)		<0.001				<0.001		0.001				0.001
Total Manganese (mg/L)		0.003	0.002	0.003	0.001	0.002		0.009	0.005	0.003	0.002	0.005
Total Mercury (mg/L)	<0.00005					<0.00005	<0.00005					<0.00005
Total Nickel (mg/L)		<0.01				<0.01		<0.01				<0.01
Total Zinc (mg/L)		<0.005	<0.005	<0.005	<0.005	<0.005		0.006	0.030	0.005	<0.005	0.012
Total Tannin & Lignin (mg/L)	0.2					0.2	0.2					0.2
Faecal Coliforms	<2	<2	2	2	2	2						
Res.105C (mg/L)	29300	26700	26800	30900	31100	28960	30300	34200	31700	29700	32500	31,680
Nonfilt. Res 105 (mg/L)	5	5	4	3	3	4	6	10	15	1	3	7

rapid nitrification of ammonia (to nitrate) from septic tank filtrate by local soils and in aerobic waters as described earlier (Section 4.2.1).

Table 14 also shows most trace metals to be within normal ranges expected for coastal marine waters, although some anomalous values do appear. Total zinc concentrations were found for the most part to be below the laboratory detection limit of 0.005 mg/L, but in August 1978 a value of 0.030 mg/L was recorded near the bottom. Although this concentration is still well below the United States' E.P.A. criteria for marine aquatic life (4-day average of 0.086 mg/L and a one-hour average of 0.095 mg/L), the agency also notes that some saltwater plants can be affected at levels as low as 0.019 mg/L (E.P.A., 1986). Similarly, total iron concentrations were generally in the normal range, but in May 1978 soared to 0.500 mg/L. This exceeds the provincial working criterion for the protection of marine aquatic life of 0.3 mg/L total iron, although if the iron is primarily bound to suspended sediments, it does not pose a threat (Pommen, pers. com.,1991). The May and August sub-surface samples also showed elevated concentrations of copper, to 0.002 mg/L and 0.003 mg/L respectively. These values are equal to the approved provincial criteria for the protection of aquatic life which require that maximum total copper concentration not exceed 0.003 mg/L and that the 30-day average should be less than or equal to 0.002 mg/L (Singleton, 1987). Whether these metal concentrations are anomalous values or whether they represent real conditions is unknown. It is possible that the elevated metal measurements are a consequence of sampling too close to bottom sediments. Some evidence to support this suggestion is provided by the fact that sub-surface phosphorous concentrations on these dates were also somewhat high, as discussed above. In addition, sub-surface nonfilterable residue (suspended solids) values corresponding to the May and August sample dates were also elevated, further suggesting that these samples may have been collected in close proximity to the bottom sediments. However, it is also conceivable that the heavy boating activity in the harbour may be impacting water column metal concentrations. For example, a surface total copper value of 0.002 mg/L collected in May, 1978 is equal to one of the provincial copper criteria. Lack of sufficient data and adequate replication make interpretation difficult and further sampling is indicated.

Dissolved oxygen (D.O.) values reported in Table 14 indicate surface concentrations were not high but were generally adequate to support aquatic life. The range of surface values (6.4 - 10.2 mg/L) is typical of a confined water body that experiences reduced circulation and mixing. During periods of high-amplitude, rapid tides or strong winds, surface waters will experience higher concentrations of D.O. due to the intrusion of oxygen-rich Malaspina Strait water or atmospheric re-oxygenation. The three-day flushing time more typical of Pender Harbour, however, can be expected to generally result in slightly reduced D.O. levels due to biological demand. Sub-surface D.O. levels were lower than surface values but show no evidence of anoxia. These depressed D.O. levels may cause oxygen distress in some marine life (Davis, 1975), and it is expected that more sensitive species would avoid these deeper waters.

5.3 SUMMARY OF WATER QUALITY

No other empirical water quality data are available for Pender Harbour, but projected inputs from point and non-point sources (as estimated in Sections 4.1 and 4.2) provide some insight as to areas of concern. Although suspended solids, 5-day BOD, and phosphorus inputs will be marginally increased in the harbour, these contaminants are not anticipated to cause any adverse impacts unless they are able to accumulate over relatively long periods of time. This is a possibility if thermal stratification isolates deep water in the harbour as described in Section 4.1.7, but even if this occurs, widespread impacts should only ensue for short periods of time during destratification.

A more serious threat to water quality is posed by bacterial and nitrogenous inputs to the harbour. The impact from bacterial inputs is already evident through the shellfish harvesting closures, and further deterioration could occur as the population and usage of the area continues to grow. The contribution of bacterial loading to the harbour from permitted discharges is predicted to be very low, but tile field drainage, agriculture, and sewage discharge from boats are likely to have a much more significant impact. Faecal coliform inputs (or other bacteriological indicators) tend to occur close to shore and in shallow water so they are often in direct conflict with shellfish populations and some recreational activities, even though the harbour as a whole has sufficient volume to dilute inputs to safe levels. Although bacteriological concentrations within the harbour are generally of an acceptable level for primary-contact recreation, isolated incidents of unacceptable levels have been recorded (Section 5.1).

The largest source of nitrogenous inputs to the harbour is expected to be from septic tank and tile field leachate, but permitted discharges and boats also contribute significant loads. Estimated total daily nitrogen loads from PE-4728, PE-8384, and septic leachate are 225 g, 104 g, and 15,300 g, respectively, and total daily nitrogen loading from boats was estimated at 550 g (Section 4). The sum of these inputs gives a total daily nitrogen load of at least 16,179 g. With a mean harbour volume of 35,000,000 m^3, the daily increase in nitrogen concentration from these sources can be calculated as 4.6×10^{-4} mg/L. If an additional allowance is made for a three-day residence time (Section 2), then increases in nitrogen concentration may be about 1.4×10^{-3} mg/L. Such an increase in concentration is very small in comparison with normal background levels expected in Pender Harbour. A number of factors could operate to elevate this concentration to levels where impacts may occur. As with bacterial sources, most nitrogenous inputs enter the water near to shore in shallow water, and these shallow areas may experience considerably higher nitrogen concentrations. Also, if mixing is poor or if flushing rates are extended due to a series of low-amplitude tides, larger amounts of nitrogen will accumulate. The potential for entrapment of nutrients in deep water is also a possibility which may result in elevated nutrient levels. Impacts from such enrichment would be expected to be primarily stimulation of primary productivity with attendant decreases in water clarity, but increased plankton growth can have additional ramifications such as toxic blooms or depletion of dissolved oxygen. Based on modelling of existing permitted discharges (Section 4.1.7), such events can be expected to be of a relatively short-lived, minor nature in Pender Harbour if they occur at all.

Depending on the form of the nitrogenous compounds, nitrogen accumulations of sufficient concentration can have impacts other than increases in productivity. Un-ionized ammonia, a fraction of total ammonia, is toxic to marine aquatic life. Total ammonia can exceed provincial criteria at concentrations as low as 0.10 mg/L given the right combination of pH, temperature, and salinity (Nordin, 1990). Under ambient conditions more typical of summer conditions in Pender Harbour (i.e., pH=8.2, temperature=20°C, salinity=$20^{o}/_{oo}$), the average 5 to 30 day concentration of total ammonia nitrogen for protection of saltwater aquatic life is 0.66 mg/L (this threshold shifts dramatically with shifts in pH, temperature, and salinity). Whether such concentrations may actually occur in deeper, trapped water in Pender Harbour is unknown and can only be determined through sampling.

Other potential impacts on water quality include effects from copper, TBT, and PAHs associated with boating use (Section 4.2.2). Predictions of input levels of these compounds are exceedingly tenuous and field sampling is the only practical method for ascertaining concentrations in Pender Harbour. Levels of TBT are expected to decline with recent use restrictions. This decline is likely to be balanced by a corresponding increase in use of copper based antifoulant paints.

In general, water quality impacts in Pender Harbour are anticipated to be most pronounced during the summer tourist season due to a combination of circumstances:

i) The local population swells considerably during this period with commensurate increases in sewage production and septic leachate.

ii) The number of boats and the activity level of boats in the harbour can be expected to increase during the good weather. Boating related inputs to the harbour can be expected to increase proportionately.

iii) Thermal stratification of the water column is likely to occur in the summertime and this will restrict mixing and effectively reduce the available diluting volume of the harbour. It may also serve to trap and retain some materials in the deeper waters of the basin.

iv) Reduced precipitation during the summer will minimize landwash (this is particularly important in the Gunboat Bay area), but it will also reduce the overall flushing rate of the harbour.

v) Increased sunlight in the summer stimulates increased plankton growth.

In spite of these factors, available evidence suggests that water quality in Pender Harbour has not deteriorated to a large extent. Although shellfish harvesting has been closed, such closures occur at very low bacterial concentrations. These concentrations can occur in the presence of relatively low numbers of humans or animals and are very difficult to avoid. It is nevertheless important to understand that further increases in input levels could jeopardize primary-contact recreation. This, coupled with concerns for possible impacts from nitrogen loading, suggests that some preventative measures may be appropriate. Several measures are available that would serve to control or reduce loading to the harbour:

i) Follow-up efforts to the Kwong & Weston (1978) survey should be continued to ensure that all illegal direct discharges are removed and that all malfunctioning septic tanks and tile fields are repaired, or alternate disposal arranged.

ii) Proper public toilet facilities should be provided at all major marinas and docks, particularly the government wharves at Hospital Bay and Madeira Park. Signs and public education should encourage boaters to use onshore facilities if they do not possess sewage holding tanks.

iii) Sewage pumpout facilities should be provided for boaters.

iv) Local farmers should be educated as to the consequences of grazing their animals along watercourses draining into Gunboat Bay and encouraged to undertake preventative measures.

v) A growing population and poor soil conditions suggest that in the long-term, the community should be planning for a trunk sewer line with appropriate treatment and disposal to service the area.

Local perceptions as to water quality vary. Some residents complained of a deterioration in water quality, whereas others reported that water quality is currently better than it has been in years. Such divergent views probably reflect that the truth lies somewhere between.

6. WATER QUALITY OBJECTIVES

6.1 WATER QUALITY OBJECTIVES - DEFINITION

Water quality objectives are established in British Columbia for waterbodies on a site-specific basis. The objective can be a physical, chemical, or biological characteristic of water, biota, or sediment, which will protect the most sensitive designated water use at a specific location with an adequate degree of safety (M.O.E., 1986). The objectives are designed to protect the designated water use with due regard to ambient water quality, aquatic life, waste discharges, and socio-economic factors.

Water quality objectives are based upon approved or working water quality criteria which are characteristics that must not be exceeded to prevent specified detrimental effects from occurring to a water use (M.O.E., 1986). In instances where approved water quality criteria are not available or where insufficient data exists, provisional water quality objectives may be set. Provisional objectives are subject to revision in light of new data as provided by monitoring or establishment of approved criteria. The B.C. Ministry of Environment, Lands and Parks is in the process of developing approved criteria for water quality characteristics throughout British Columbia, to form part of the basis for permanent objectives.

The objectives consider the use of the water to be protected and the existing water quality. They allow for changes from background which can be tolerated, or for upgrading which may be required. Objectives do not apply to initial dilution zones of effluents. In marine waters, these zones are usually defined as extending up to 100 m horizontally in all directions from the discharge, but not to exceed 25% of the width of the water body. In practice, small volume discharges or discharges with low levels of contaminants will require mixing zones much smaller than the maximum initial dilution zone allowed. The concentrations of contaminants permitted in effluents are such that levels in the initial dilution zones will not be acutely toxic to aquatic life or create objectionable or nuisance conditions. Processes such as chemical changes, precipitation, adsorption, and microbiological action, as well as dilution, take place in these zones to ensure that water quality objectives will be met at their borders.

The objectives can be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. They have no legal standing and their direct enforcement would not be practical.

6.2 DESIGNATED WATER USES

To ensure that present and future water uses of Pender Harbour are protected, the following designated water uses are proposed:

- Primary-contact recreation, including swimming, SCUBA diving, wading, wind surfing, etc.
- Secondary-contact recreation, primarily boating.
- Fisheries
- Shellfish
- Waterfowl

The following water quality objectives are designed to protect the most sensitive designated water use. If the objectives are met for the most sensitive use, then all other uses of the harbour will also be protected. Unless expressly noted otherwise, all designated water uses and objectives apply to the entire study area, including the main basin of Pender Harbour, Gunboat Bay, Oyster Bay, East Bay, and Bargain Bay.

6.3 OBJECTIVES

6.3.1 Microbiological Indicators

The most sensitive use impacted in Pender Harbour by microbiological factors is the harvesting and consumption of shellfish. This use has already been addressed by the federal Environmental Protection Service which has closed the entire area to shellfish harvesting based on the terms of their faecal coliform criteria (Section 5.1) and/or sanitary surveys. Shellfish harvesting in Pender Harbour is also confined by the large number of sizable wharves and marinas in the harbour. Under regulations set out in the Fisheries Act, the Environmental Protection Service routinely imposes "wharf closures" on waters within 125 m of large, multi-use docks. This is a standard procedure designed to prevent harvesting of shellfish from waters potentially contaminated by boat sewage. Even without the blanket closure now in effect in Pender Harbour, large sections of harbour shoreline would likely remain unavailable for shellfish harvesting due to these wharf closures.

Whereas there is some opportunity for improvement in bacterial water quality in Pender Harbour, the consistent maintenance of bacterial concentrations below the stringent criteria required for harvesting shellfish does not appear to be a realistic goal in the near future. Even if aggressive measures are undertaken to control bacterial inputs to the harbour, it is not clear that they would be adequate to achieve consistent, satisfactory water quality for the growing of shellfish. Such measures would necessarily include provision of a trunk sewer line to replace existing septic fields, prevention of all boats from discharging wastes into the harbour, and elimination of all agricultural wastes reaching the harbour. While these actions would substantially improve the bacterial water quality of the harbour, landwash from such a developed area would likely still provide significant bacterial loading to the harbour, particularly during periods of high rainfall. In a confined water body such as Pender Harbour, with restricted flushing and moderately developed uplands, this landwash alone would likely compromise water quality beyond acceptable bacterial limits for the recreational harvesting of shellfish. This fact, combined with the possibility of accidental discharge from boats, leaking sewer lines etc., would still present an unacceptable risk for the safe human consumption of shellfish from Pender Harbour.

These factors dictate that it is not currently feasible to designate shellfish harvesting as the most sensitive water use in Pender Harbour for the purposes of water quality objectives.[2] In consequence, primary-contact recreation is therefore designated as the most sensitive water use requiring protection from bacteriological contamination in the harbour. The proposed provisional objectives for microbiological indicators in Pender Harbour correspond to the draft federal-provincial criteria for marine water used for primary-contact recreation (Federal-Provincial Working Group on Recreational Water Quality, 1990). These criteria require that the geometric mean of at least five samples, taken during a period not to exceed thirty days, should not exceed 350 enterococci per litre. Sampling should be repeated if any individual sample exceeds 700 enterococci/L. These new criteria rely on enterococci as the best biological indicator for marine waters, as these bacteria are known to persist longer in salt water than do faecal coliforms, and demonstrate a positive correlation with gastrointestinal illness (Federal-Provincial Working Group on Recreational Water Quality, 1990).

Bacteriological objectives for Bargain Bay require separate consideration from the main body of Pender Harbour due to the more favourable water quality conditions evident there. Bargain Bay has much lower boating density and has none of the large wharves characteristic of the rest of Pender Harbour. Also, Bargain Bay is open to the south and is not confined by a sill, so flushing is expected to be relatively rapid and complete with each tidal cycle. These factors are consistent with the generally superior bacteriological water quality of the bay as compared to Pender Harbour (Section 5.1). Only one sample station in Bargain Bay has failed to meet shellfish growing standards, and it is possible that this failure may be attributable to a single illegal discharge. The other main source of bacterial input to Bargain Bay is likely landwash from developed properties and septic fields, although there is little evidence of this from available data. Upgrading of existing septic systems or eventual replacement with a trunk sewer line should reduce microbiological inputs to a minimum and render most, if not all, of Bargain Bay suitable for harvesting shellfish. The proposed provisional objectives for microbiological indicators in Bargain Bay are accordingly to protect the water for the growing, harvesting, and human consumption of marine shellfish. Specifically, the faecal coliform concentrations in Bargain Bay should not exceed a median of 14/100 mL over 30 days, and at least 90% of the samples in a 30-day period should not exceed 43/100 mL. The Environmental Protection Service ultimately determines whether or not a given area can be used for harvesting shellfish, but the local demand for recreational harvesting opportunities and the existing water quality suggest that Bargain Bay is a good candidate to target for this purpose.

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[2] While it is not currently considered practical to consistently achieve shellfish growing water standards in Pender Harbour, future improvements such as the construction of a sewage collection system, prevention of vessel discharges, and better agricultural practices will necessitate a re-evaluation of microbiological water quality objectives in the harbour. It would in any case be prudent to strive to attain shellfish standards due to the fact that some people reportedly disregard the current harvesting restrictions and consume shellfish from these waters.

6.3.2 Nitrogen

Inorganic nitrogenous inputs to Pender Harbour could potentially impact water quality due to the stimulation of primary productivity and associated effects. Some of these "associated effects" such as toxic blooms, and dissolved oxygen depletion can have serious implications for several water uses. Nitrite, nitrate, and ammonia can all promote primary productivity, but different phytoplankton species have different requirements for these nutrients and nutrient limitation can occur at a wide range of concentrations. Since primary productivity is also regulated by a multitude of other factors such as amount of light, temperature, tides, biological activity, and salinity, it is apparent that productivity mechanisms are complex. This complexity, combined with the large natural variability of these nitrogenous species in marine waters, make it very difficult to predict what concentrations will provoke significant productivity enhancement. No working or approved provincial criteria exist to address this problem.

The ability to evaluate the impacts of nutrient loading to an embayed area may be most effectively addressed by examining changes in the sediment rather than instantaneous water column measurements of inorganic nitrogen concentrations. Sediment measurements of such things as rates of microbial mineralization potential and epibenthic microalgal production have been shown to integrate short-term nutrient fluctuations (Gillespie *et al.*, 1990). Such analysis is not currently common practice and further work in this field remains to be done before these kinds of techniques can be routinely implemented. Until such time as workable water quality criteria have been developed, no nitrogen concentration objectives relating to primary productivity or nutrient enrichment will be proposed here.

Although the productivity impacts of nitrogen enrichment are difficult to assess, the toxic effects of ammonia are well documented. Ammonia in water normally exists in an equilibrium consisting of molecular ammonia (un-ionized ammonia or NH_3) and the ammonium ion (NH_4^+) with the relative proportions between these two forms determined by ambient temperature, salinity, and pH (Nordin & Pommen, 1986). At sufficient concentrations, un-ionized ammonia is known to be toxic to aquatic life, but these concentrations are unlikely to occur under normal circumstances in Pender Harbour. A possible exception are the deeper waters of the basin which may experience pronounced nutrient enrichment if this water becomes "trapped" during thermal stratification. Under these conditions, ammonia toxicity could potentially occur both in the deeper water and also more generally throughout the harbour during the mixing that would occur during de-stratification. Accordingly, the recommended provisional objectives for ammonia nitrogen in Pender Harbour are the approved provincial criteria for the protection of marine aquatic life as given in Tables A and B, Appendix II. These tables express the criteria both as a maximum (Table A) and as an average 5 to 30-day concentration (Table B), and are temperature, salinity, and pH dependent.

At sufficiently high concentrations, nitrite is also known to be toxic to fish . However, in the marine environment, nitrite occurs at low concentrations and is most commonly viewed as a transitional compound in the oxidation of ammonia to nitrate. The U.S. Environmental Protection Agency regards the occurrence of toxic concentrations of nitrite in nature to be unlikely and has therefore chosen not to recommend restrictive criteria for this compound (E.P.A., 1986). Provincial criteria are also unavailable. Since the limited existing nitrite data for Pender Harbour (<0.005 - 0.014 mg/L, Table 14) are within the normal coastal range of concentrations (0 - 0.028 mg/L, Sharp, 1983), no nitrite objectives are proposed for the harbour.

6.3.3 Copper

Antifoulant paints and copper fittings on the large number of boats common in Pender Harbour could potentially elevate copper concentrations in the waters and sediments of the harbour (Section 4.2.2.2). The recent prohibition on use of TBT antifoulants and a consequent reemphasis on copper-based bottom paints will exacerbate this problem. Although the volume and regular flushing of the harbour make it unlikely that water column concentrations will reach very high levels, it is possible that unsafe copper concentrations may occur in the waters and sediments adjacent to large marinas. Some indication of elevated copper levels was evident in the limited water sampling conducted in 1978 (Section 5.2, Table 14).

The proposed provisional water quality objective to protect aquatic life in Pender Harbour is in accordance with the approved provincial criteria: the maximum total copper concentration is not to exceed 3 µg/L and the 30-day average should be less than or equal to 2 µg/L (Singleton, 1987). No provincial criteria are available for sediment trace metals, although Swain & Nijman (1990) have developed protocols for determining sediment quality objectives for Burrard Inlet. These objectives were based on three sources of data: i) the Apparent Effects Threshold (AET) as developed by the Washington Department of Ecology for Puget Sound, ii) mean sediment values as obtained from a reference site in Outer Burrard Inlet, and iii) mean sediment values from reference sites elsewhere in B.C. In the absence of reference sediment data in the Pender Harbour area, it is not possible to follow the same procedure to develop sediment objectives unique to Pender Harbour. It is therefore proposed that until such time as reference data for the harbour are available (see Section 6.4 for proposed monitoring program), the provisional sediment quality objective as set for Burrard Inlet be adopted for Pender Harbour, i.e., sediment copper concentrations should not exceed 100 µg/g dry weight (Swain & Nijman, 1990). The rationale for adopting this provisional objective is that some allowance is made for anthropogenic inputs of copper while at the same time concentrations are required to remain well below the AET of 310 µg/g dry weight set for Puget Sound (Department of Ecology, 1989). A similar approach is appropriate for Pender Harbour where it is realistic to expect some impact to the sediments due to extensive boat use, but it is still necessary to protect aquatic life. A maximum copper sediment objective of 100 µg/g is also in good agreement with the Effects Range-Low (ER-L) value for copper of 70 µg/g (Long & Morgan, 1990). The ER-L represents the lower 10 percentile concentration (from a wide survey of biological effects data) that causes or predicts biological effects from sediment-sorbed contaminants.

6.3.4 Zinc

Zinc is a prevalent metal around marinas where it is common in galvanized materials and is often used as sacrificial anodes to prevent electrolysis on boats. Zinc levels were found to be somewhat elevated on at least one occasion in Pender Harbour (Section 5.2) and have been shown elsewhere to be present in the sediments around marinas in increased concentrations (Crecelius *et* *al.*, 1990). A provisional water quality objective is therefore proposed to protect marine aquatic life. Although the E.P.A. total zinc criteria for the protection of aquatic organisms specifies a maximum 4-day average of 0.086 mg/L and a maximum 1-hour average of 0.095 mg/L (E.P.A., 1986), biological effects are known to occur at much lower concentrations of this metal. Accordingly, Pommen (pers. com., 1991) recommends an appropriate provisional objective for dissolved zinc of 0.015 mg/L. A similar criterion level can be applied to the total zinc fraction if suspended solids are negligible or absent.

As is the case for copper, zinc concentrations in the sediments may provide a better measure of the long-term relative abundance of this trace metal than does zinc in the water column. In the absence of reference sediment data for Pender Harbour and using the same rationale as for copper, it is recommended that the sediment objective for zinc as determined for Outer Burrard Inlet be adopted as the provisional sediment objective for Pender Harbour. This objective sets a maximum concentration of zinc in the sediment at 150 µg/g dry weight (Swain & Nijman, 1990), and is in reasonably close agreement with the ER-L value for zinc of 120 µg/g (Long & Morgan, 1990). This objective is subject to revision once reference data become available for Pender Harbour.

6.3.5 Lead

Lead has until recently (1991) been a common fuel additive and is also widely used in marine applications as a ballasting material. Marinas studied in Washington State have shown evidence of increased lead concentrations in adjacent sediments (Crecelius *et al.*, 1990), and it is therefore considered prudent to designate objectives for this heavy metal in Pender Harbour. The proposed provisional water quality objectives for lead to protect aquatic life in Pender Harbour are the same as the approved provincial criteria:

i) The average concentration of total lead in water over a 30-day period (based on a minimum of 5 weekly samples) should not exceed 2 µg/l. Not more then 20% of the values in a 30-day period should exceed 3 µg/l.

ii) The maximum concentration of total lead in water at any time should not exceed 140 µg/l (Nagpal, 1987)

Water samples from Pender Harbour have only been analyzed for lead content on one occasion (May 1978) and the results from those samples showed lead concentrations to be at or below detection limits (1 μg/L, Table 14). Further sampling is required to ensure that the lead objectives/criteria are being met.

As before, sediments are a more meaningful measure of abundance of trace metals than are water column measurements. No ambient sediment lead data are available for Pender Harbour, so the interim proposed sediment objective to protect aquatic life in the harbour is the same as that given for Burrard Inlet, 30 μg/g dry weight (Swain & Nijman, 1990). The objective may be adjusted once reference data become available for Pender Harbour. This value is somewhat higher than the normal background range of lead levels in coastal waters of from <10 to <20 μg/g (Nagpal, 1987), but is only 10% of the lowest Puget Sound AET of 300 μg/g (Department of Ecology, 1989), and is slightly more conservative than the ER-L value of 35 μg/g (Long & Morgan, 1990). Thus, some allowance is made to accommodate a degree of lead loading while still protecting aquatic life.

Due to the abundance of finfish and shellfish resources in Pender Harbour, an additional provisional lead objective is proposed to maintain tissue lead concentrations in these resources at levels considered safe for human consumption. The approved provincial criteria for lead states that total lead concentrations in the edible portions of fish/shellfish should be considered potentially hazardous if they approach or exceed 0.8 μg/g wet weight (Nagpal, 1987). This value is therefore proposed as an alert level for Pender Harbour and tissue total lead levels in this range should initiate a more intensive site-specific investigation. Note that because of their close proximity to the sediments and their lack of mobility, shellfish should be considered particularly vulnerable to lead contamination. It is particularly important that the commercially grown oysters from Oyster Bay, even though subject to depuration before processing, should conform to this objective. Likewise, shellfish resources in Bargain Bay should also comply with this objective if recreational harvesting in the bay is to be permitted in the future.

6.3.6 Iron

The working provincial iron criteria to protect marine aquatic life consider a minimal risk to exist when total iron concentrations reach 0.05 mg/L and a hazardous condition to exist when levels reach 0.3 mg/L (Pommen, 1991). The hazardous level was surpassed in a water sample collected in 1978 (Section 5.2), but it is unlikely that this water actually constituted a threat to aquatic life unless ithe iron was biologically available. Provincial criteria are expressed in terms of total iron, whereas it is actually primarily the dissolved component and precipitates that represent a hazard to sealife (Pommen, pers. com., 1991). The high value (0.500 mg/L) obtained in 1978 most likely reflected high levels of iron complexed with suspended sediments and in this form iron toxicity is not anticipated. In the absence of concurrent dissolved metal analysis, however, this interpretation cannot be stated with certainty and additional sampling is indicated. The proposed provisional objective is therefore set at a total iron concentration of 0.05 mg/L with the caveat that subsequent interpretation is required to establish whether the iron exists principally in the dissolved form or is complexed with the suspended sediments.

6.3.7 Tributyl Tin

Levels of TBT in Pender Harbour are expected to be on the decline due to recent regulations severely restricting its use (Section 4.2.2.2). The proposed provisional TBT objective is 0.001 µg/L for the protection of marine aquatic life in Pender Harbour. This figure is based on the recommended maximum level as set forth by the Canadian Water Quality Guidelines (Moore *et al.*, in press, 1991)). Although a sediment criterion for this contaminant would be appropriate, a paucity of regional reference data and the lack of AET values for butyltins prevent the formulation of a meaningful sediment objective for TBT in Pender Harbour. Butyltins have been found in increased concentrations in sediments adjacent to two Washington State marinas (Crecelius *et al.*, 1990), but no sediment objectives are proposed for Pender Harbour at this time.

6.3.8 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are minimally soluble in water and thus tend to accumulate in bottom sediments. Although subject to biodegradation, both lower-weight PAHs and higher-weight PAHs have been shown to occur in elevated concentrations in the sediments around marinas (Crecelius *et al.*, 1990). The Province of British Columbia is currently developing water quality criteria for these compounds, but Swain and Nijman have already proposed PAH sediment objectives for Burrard Inlet (Swain & Nijman, 1990). In the absence of ambient sediment PAH data for Pender Harbour, it is proposed that Swain and Nijman's rationale for the development of Burrard Inlet objectives be similarly applied to Pender Harbour. Burrard Inlet objectives were established at one tenth of the concentrations of the lowest Puget Sound AETs with resulting values required to be at least two to three times the analytical detection limit for the PAH. The resulting provisional sediment objectives to protect marine aquatic life in Pender Harbour are given in Table 15. Note that in most cases, the proposed objectives are more stringent than the corresponding ER-L values developed by Morgan and Long (1990).

Table 15. Polycyclic Aromatic Hydrocarbon (PAH) Sediment Objectives for Pender Harbour (µg/g dry-weight)

Lower Weight PAH's	Lowest AET	ER-L	Objective	Higher Weight PAH's	Lowest AET	ER-L	Objective
Σ LPAH	5.2		0.5	Σ HPAH	12.0		1.2
Naphthalene	2.1	0.340	0.2	Fluoranthene	1.7	0.60	0.17
Acenaphthylene	0.56		0.06	Pyrene	2.6	0.35	0.26
Acenaphthene	0.5	0.150	0.05	Benzo(a)anthracene	1.3	0.23	0.13
Fluorene	0.5	0.035	0.05	Chrysene	1.4	0.40	0.14
Phenanthrene	1.5	0.225	0.15	Benzofluoranthenes	3.2		0.32
Anthracene	0.96	0.085	0.10	Benzo(a)pyrene	1.6	0.40	0.16
				Indeno(1,2,3-cd)pyrene	0.6		0.06
				Dibenzo(a,h)anthracene	0.2	0.06	0.06
				Benzo(g,h,i)perylene	0.7		0.07

6.3.9 Dissolved Oxygen

Under normal circumstances, dissolved oxygen concentrations are not anticipated to jeopardize any of the designated water uses in Pender Harbour. Possible exceptions may occur if water in the deepest part of the harbour basin is trapped and unable to mix with shallower more oxygenated water. The biological oxygen demand (BOD) of this trapped water could lead to some degree of oxygen depletion in this zone. If such entrapment occurs, it can be regarded as a natural phenomenon and biota living in this zone can be expected to be tolerant of diminished dissolved oxygen concentrations. A potential danger to aquatic life lies in the possibility of such oxygen-deficient water surfacing during periods of vigourous mixing and destratification. Widespread oxygen deficiencies may also occur during senescence of major phytoplankton blooms due to bacteriological breakdown of the dead cells, although normally such events are quite rare.

Regardless of the mechanism of oxygen reduction, widespread oxygen deficiencies are not expected to persist in Pender Harbour, if in fact they occur at all. Tidal flushing and mixing should restore oxygenated water to the harbour relatively rapidly. Nevertheless, if even short pulses of reduced dissolved oxygen occur, aquatic life may be threatened. For this reason, a provisional dissolved oxygen objective is proposed for Pender Harbour. According to the provincial working criteria for dissolved oxygen, non-anadromous fish species are afforded a moderate level of protection at a minimum concentration of 6.75 mg/L (Pommen, 1991) and this is the proposed objective for Pender Harbour. This objective also offers moderate protection to anadromous species, including salmonids, which have a comparable dissolved oxygen criterion of a minimum of 6.5 mg/L. A moderate level of protection is considered appropriate for Pender Harbour in view of the fact that dissolved oxygen levels appear to be naturally depressed in the harbour from the limited amount of available data (Section 5.2, Table 14). Additional data will necessitate a review of the dissolved oxygen objective for Pender Harbour.

6.3.10 OIL AND GREASE

Aside from any toxic components they may contain (i.e., PAHs), oil and grease films are aesthetically unpleasant and may interfere with swimming and other water activities. In addition, oil films present a hazard to waterfowl and are presumably unhealthy for other biota living on or near the water surface. Sampling and analysis problems associated with measurement of oil and grease make it very difficult to develop a practical, quantifiable criteria or objective, although the Canadian Water Quality Guidelines state that oil and grease should not be detectable by sight or smell if waters are to be used for recreational purposes (CCREM, 1987). It is obviously in all users' best interests to reduce nuisance fuel slicks as much as possible, but it is also probably unrealistic to expect complete eradication in a busy harbour such as Pender Harbour that is frequented by boats and has two marine fuel outlets. These considerations make it impractical to prescribe a formal objective for oil and grease levels in Pender Harbour, although it is recognized as a nuisance condition that should be minimized to the greatest extent possible.

Allegations have been made by local residents of Pender Harbour that at least one marina operation has refuelling facilities on their docks that have not been subject to proper inspection. It is recommended that all marina operations be inspected by authorized personnel (i.e., Fire Department) to insure that adequate refuelling equipment and procedures are in place. Improper hoses, joins, etc. may result in a potentially devastating fuel spill in the harbour, as well as jeopardize human safety.

6.4 MONITORING

Monitoring is required in Pender Harbour to provide three kinds of information. First, it is essential to establish whether or not water is trapped in deeper portions of the harbour basin or if it is routinely mixed and flushed. Second, ambient data are required to support the proposed objectives. Other than for microbiological indicators, very few recent ambient data were available for Pender Harbour. Third, a monitoring program will allow an assessment as to whether or not water quality objectives are being met. The proposed monitoring program is designed from a technical perspective to fulfill all three of these objectives, but the actual extent of monitoring may be confined by limited monitoring resources or other priorities.

Although the federal Environmental Protection Service continues to sample Pender Harbour, not all bacteriological characteristics specified in the objectives are measured. E.P.S. monitoring efforts are directed towards testing water quality for suitability for shellfish resources and do not directly address primary-contact recreation concerns. For this reason, it is recommended that the Ministy of Environment, Lands and Parks select several sites in Pender Harbour and sample for enterococci, as well as faecal coliforms. Sample sites should be selected to coincide with areas most likely to experience recreational use, such as the major government wharves, marinas, and any beach areas. Sampling should be conducted in the summer tourist season when the local population and the numbers of boats are at their maximum. At all sample sites, a minimum of 5 samples should be collected within a 30-day period. In Bargain Bay, additional sites should be selected at beaches supporting shellfish populations of recreational interest. Membrane filtration is the recommended analytical technique to be used for both enterococci and faecal coliform.

Suggested locations for measurement of non-bacteriological contaminants are shown in Figure 8. Note that station B just east of the Skardon Islands is located at the point of greatest depth in the harbour (44 m). Station F in the centre of Bargain Bay can be regarded as a reference station for sediment samples. Station G is arbitrarily located adjacent to the Madeira Park Government Wharf, but could alternatively be located near any major marina facility in the harbour. The following monitoring outline suggests recommended timing and frequency of non-bacteriological sampling and refers to the possible station locations given in Figure 8.

1. A temperature/salinity/dissolved oxygen profile should be performed at stations A through F on a monthly basis for a period of one year. Measurements should be taken from 0-10 m at 2 m increments, and thence every 5 m to the bottom. Presence or absence of surface oil or grease should also be noted on all occasions.

2. At station B, surface, near-surface, mid-depth and bottom measurements of ammonia, nitrite, and nitrate should be collected on five occasions during a thirty-day period in late

summer. Temperature, salinity, dissolved oxygen, and pH data should be collected concurrently.

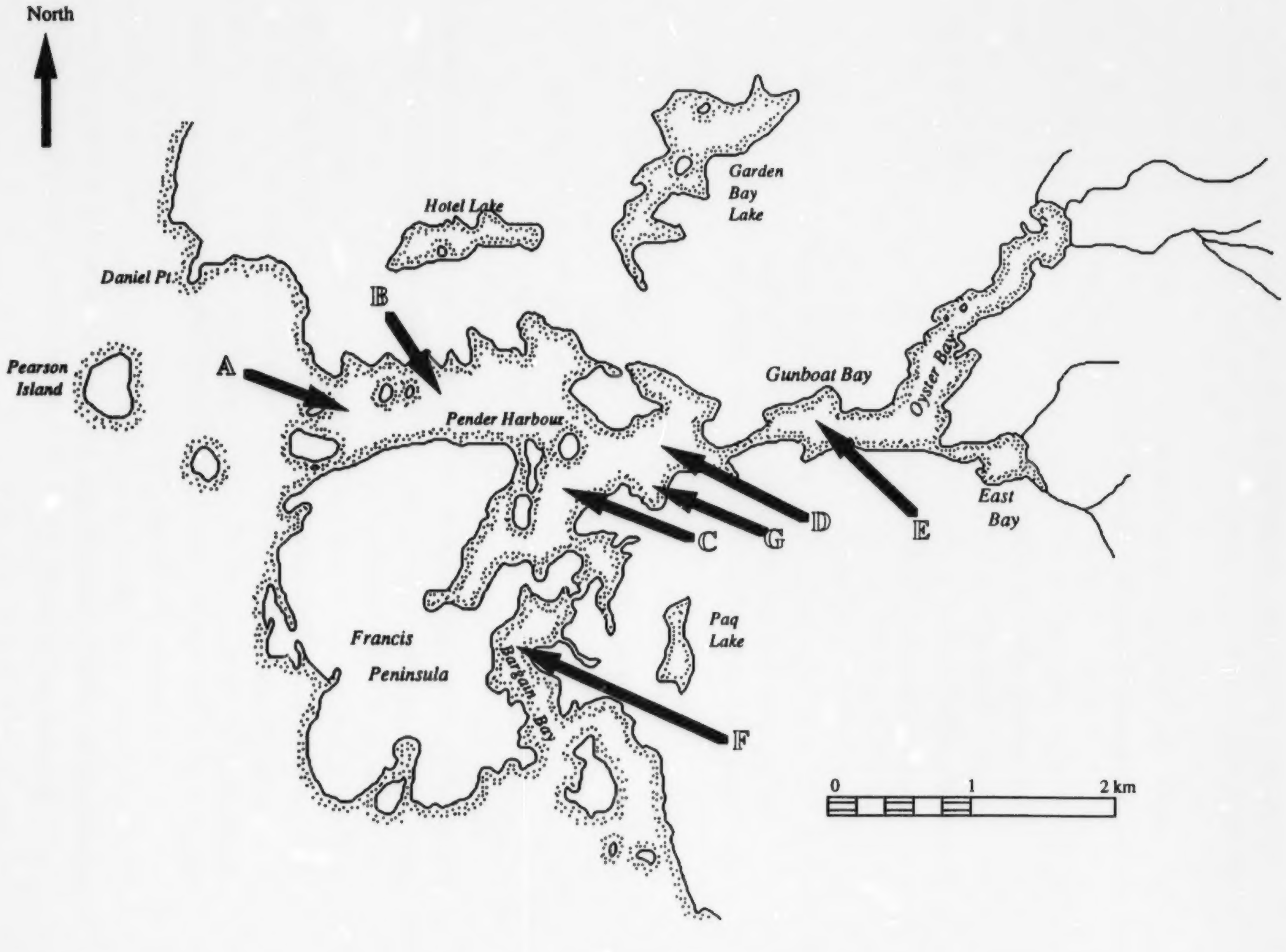
3. At stations G and F, surface and near-bottom water samples should be collected on five occasions during a thirty-day period in late summer and analyzed for total and dissolved copper, zinc, lead, iron, and TBT. Concurrently, sediment samples should be obtained on the same dates and at the same locations and analyzed for copper, zinc, lead, and TBT. No TBT sediment objective has been established for Pender Harbour, but sediment data would be useful to compare with other areas and to establish a data base.

4. A minimum of three oyster samples (minimum of one gram of tissue per sample) should be collected from Oyster Bay and three oyster or clam samples from Bargain Bay. Edible tissues from these samples should be analyzed for total lead content.

5. A site should be selected adjacent to one of the fuel docks in the bay and a minimum of three replicate sediment samples should be collected and analyzed for PAH.

6. Quality Assurance (QA) aspects of this recommended monitoring program should include adequate sample replication and testing of "blanks" and referenc samples in accordance with the Ambient Water Quality Monitoring Program.

Figure 8. Proposed Monitoring Sites in Pender Harbour


North
Pearson Island
Daniel Pt.
Hotel Lake
Garden Bay Lake
Pender Harbour
Gunboat Bay
Oyster Bay
East Bay
Francis Peninsula
Bargain Bay
Paq Lake
A
B
C
D
E
F
G
0
1
2 km

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APPENDIX I

Bacteriological Data From Pender Harbour

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
EPS	74	4-Jul	2	Neck of East Pender Bay	1000	16.0	20.8	540.0	540.0					
EPS	74	4-Jul	2	Neck of East Pender Bay	1630	17.0	19.9	110.0	22.0					
EPS	74	5-Jul	2	Neck of East Pender Bay	1615	18.5	17.3	70.0	23.0					
EPS	74	8-Jul	2	Neck of East Pender Bay	1325	19.0	19.0	240.0	130.0					
EPS	74	9-Jul	2	Neck of East Pender Bay	0855	20.0	16.5	540.0	170.0					
EPS	74	9-Jul	2	Neck of East Pender Bay	1620	17.5	14.2	350.0	350.0	295.0	113.3	150.0	66.7	16.7
EPS	74	3-Jul	5	Oyster Bay @ narrows	1635	16.0	24.3	220.0	49.0					
EPS	74	4-Jul	5	Oyster Bay @ narrows	0945	15.0	14.2	540.0	49.0					
EPS	74	4-Jul	5	Oyster Bay @ narrpws	1415	16.5	15.9	350.0	240.0					
EPS	74	5-Jul	5	Oyster Bay @ narrows	1420	20.5	15.3	49.0	13.0					
EPS	74	8-Jul	5	Oyster Bay @ narrows	1315	18.0	14.2	130.0	17.0					
EPS	74	9-Jul	5	Oyster Bay @ narrows	0900	19.5	15.9	33.0	13.0					
EPS	74	9-Jul	5	Oyster Bay @ narrows	1610	18.0	14.2	79.0	49.0	130.0	36.2	49.0	57.1	0.0
EPS	74	3-Jul	18	Oyster Bay @ entrance	1640	16.0	24.3	350.0	46.0					
EPS	74	4-Jul	18	Oyster Bay @ entrance	0950	15.0	15.9	920.0	140.0					
EPS	74	4-Jul	18	Oyster Bay @ entrance	1420	16.5	15.9	49.0	49.0					
EPS	74	5-Jul	18	Oyster Bay @ entrance	1430	18.0	18.0	49.0	6.8					
EPS	74	8-Jul	18	Oyster Bay @ entrance	1335	18.0	15.9	130.0	6.8					
EPS	74	9-Jul	18	Oyster Bay @ entrance	0905	19.5	15.9	31.0	6.8					
EPS	74	9-Jul	18	Oyster Bay @ entrance	1615	17.0	14.2	79.0	49.0	79.0	24.2	46.0	57.1	0.0
EPS	74	17-Jul	19	Entrance to Gunboat Bay	1055	16.0	13.5	170.0	33.0					
EPS	74	17-Jul	19	Entrance to Gunboat Bay	1545	16.5	14.7	22.0	1.8					
EPS	74	18-Jul	19	Entrance to Gunboat Bay	0915	16.5	13.5	110.0	49.0					
EPS	74	18-Jul	19	Entrance to Gunboat Bay	1505	17.5	14.2	22.0	17.0					
EPS	74	19-Jul	19	Entrance to Gunboat Bay	0945	17.0	13.5	130.0	9.3					
EPS	74	19-Jul	19	Entrance to Gunboat Bay	1420	17.5	14.2	26.0	4.5	68.0	11.3	13.2	16.7	0.0
EPS	74	3-Jul	20	Entrance to Garden Bay	1620	15.0	25.7	23.0	4.5					
EPS	74	4-Jul	20	Entrance to Garden Bay	0935	15.0	19.9	4.5	2.0					
EPS	74	4-Jul	20	Entrance to Garden Bay	1405	16.0	21.9	33.0	4.5					
EPS	74	9-Jul	20	Entrance to Garden Bay	0915	18.0	15.3	11.0	4.5					
EPS	74	9-Jul	20	Entrance to Garden Bay	1455	18.0	15.3	350.0	110.0					
EPS	74	10-Jul	20	Entrance to Garden Bay	1445	17.5	13.5	33.0	7.8					
EPS	74	11-Jul	20	Entrance to Garden Bay	1010	18.0	15.3	49.0	4.5					
EPS	74	11-Jul	20	Entrance to Garden Bay	1555	18.0	15.9	23.0	2.0					
EPS	74	12-Jul	20	Entrance to Garden Bay	0955	17.0	15.3	350.0	14.0					
EPS	74	15-Jul	20	Entrance to Garden Bay	1420	18.0	15.9	79.0	11.0					
EPS	74	16-Jul	20	Entrance to Garden Bay	1435	17.0	15.9	31.0	4.5					
EPS	74	17-Jul	20	Entrance to Garden Bay	0955	16.0	14.7	49.0	6.8					
EPS	74	17-Jul	20	Entrance to Garden Bay	1535	17.0	14.7	33.0	33.0					
EPS	74	18-Jul	20	Entrance to Garden Bay	0910	16.5	13.0	540.0	350.0					
EPS	74	19-Jul	20	Entrance to Garden Bay	0930	17.0	13.0	46.0	23.0	33.0	10.4	6.8	13.3	0.0

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION	STATION LOCATION	TIME	TEMP	SAL	TOTAL COLIF	FECAL COLIF	TOTAL	FECAL	FECAL	% EXCEEDING	% EXCEEDING
			NUMBER			(°C)	(ppt)	(MPN/100 mL)	(MPN/100 mL)	MEDIAN	GEO. MEAN	MEDIAN	43/100 mL	400/100 mL
EPS	74	3-Jul	22	Head of Garden Bay	1615	16.0	25.7	350.0	4.0					
EPS	74	4-Jul	22	Head of Garden Bay	0930	16.0	20.8	7.8	<1.8					
EPS	74	4-Jul	22	Head of Garden Bay	1400	16.0	21.9	<1.8	<1.8					
EPS	74	9-Jul	22	Head of Garden Bay	0910	20.0	15.3	6.8	4.0					
EPS	74	9-Jul	22	Head of Garden Bay	1450	18.0	15.3	920.0	280.0					
EPS	74	10-Jul	22	Head of Garden Bay	1440	17.5	13.5	79.0	49.0					
EPS	74	11-Jul	22	Head of Garden Bay	0543	17.5	15.3	46.0	2.0					
EPS	74	11-Jul	22	Head of Garden Bay	1555	18.0	15.9	130.0	33.0					
EPS	74	12-Jul	22	Head of Garden Bay	1000	17.0	15.3	350.0	33.0					
EPS	74	15-Jul	22	Head of Garden Bay	1425	17.5	16.5	130.0	49.0					
EPS	74	16-Jul	22	Head of Garden Bay	1435	17.5	15.9	350.0	49.0					
EPS	74	17-Jul	22	Head of Garden Bay	1000	16.0	14.7	33.0	11.0					
EPS	74	17-Jul	22	Head of Garden Bay	1540	17.0	15.3	46.0	2.0					
EPS	74	18-Jul	22	Head of Garden Bay	0905	16.5	15.3	23.0	2.0					
EPS	74	19-Jul	22	Head of Garden Bay	0935	17.0	13.5	240.0	79.0	79.0	11.9	11.0	33.3	0.0
EPS	74	3-Jul	26	NE. shore of Hospital Bay	1715	15.0	25.7	14.0	2.0					
EPS	74	4-Jul	26	NE. shore of Hospital Bay	0920	15.0	19.9	1.8	<1.8					
EPS	74	4-Jul	26	NE. shore of Hospital Bay	1345	17.0	20.8	49.0	7.8					
EPS	74	9-Jul	26	NE. shore of Hospital Bay	0850	18.0	15.3	49.0	13.0					
EPS	74	9-Jul	26	NE. shore of Hospital Bay	1505	18.0	15.3	240.0	4.5					
EPS	74	11-Jul	26	NE. shore of Hospital Bay	1030	17.0	15.3	49.0	2.0					
EPS	74	11-Jul	26	NE. shore of Hospital Bay	1605	18.0	15.3	79.0	79.0					
EPS	74	12-Jul	26	NE. shore of Hospital Bay	1010	17.0	15.3	920.0	33.0					
EPS	74	15-Jul	26	NE. shore of Hospital Bay	1435	17.5	16.5	130.0	33.0					
EPS	74	16-Jul	26	NE. shore of Hospital Bay	1455	17.5	15.9	79.0	7.8					
EPS	74	17-Jul	26	NE. shore of Hospital Bay	0945	16.0	14.2	240.0	23.0					
EPS	74	17-Jul	26	NE. shore of Hospital Bay	1330	16.5	13.5	350.0	49.0					
EPS	74	18-Jul	26	NE. shore of Hospital Bay	1000	16.5	13.5	>1600	1600.0					
EPS	74	19-Jul	26	NE. shore of Hospital Bay	1015	17.0	14.2	240.0	17.0	104.5	15.9	15.0	21.4	7.1
EPS	74	3-Jul	27	N. shore of Hospital Bay	1710	15.0	25.7	9.3	4.0					
EPS	74	4-Jul	27	N. shore of Hospital Bay	0925	15.0	19.9	27.0	1.8					
EPS	74	4-Jul	27	N. shore of Hospital Bay	1345	16.0	21.9	7.8	<1.8					
EPS	74	9-Jul	27	N. shore of Hospital Bay	0845	18.0	15.3	540.0	7.8					
EPS	74	9-Jul	27	N. shore of Hospital Bay	1505	18.0	15.3	240.0	4.0					
EPS	74	11-Jul	27	N. shore of Hospital Bay	1025	17.0	15.3	350.0	33.0					
EPS	74	11-Jul	27	N. shore of Hospital Bay	1605	17.5	15.3	17.0	7.8					
EPS	74	12-Jul	27	N. shore of Hospital Bay	1005	17.0	15.3	49.0	7.8					
EPS	74	15-Jul	27	N. shore of Hospital Bay	1430	18.0	16.5	140.0	4.5					
EPS	74	16-Jul	27	N. shore of Hospital Bay	1445	17.5	15.9	170.0	11.0					
EPS	74	17-Jul	27	N. shore of Hospital Bay	0945	15.5	26.5	130.0	33.0					
EPS	74	17-Jul	27	N. shore of Hospital Bay	1335	16.5	13.5	33.0	4.5					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
EPS	74	18-Jul	27	N. shore of Hospital Bay	0955	16.5	13.5	350.0	17.0					
EPS	74	19-Jul	27	N. shore of Hospital Bay	1015	17.0	14.2	140.0	33.0	135.0	7.8	7.8	0.0	0.0
EPS	74	4-Jul	30	N. of Williams Island	1605	15.5	20.8	<1.8	<1.8					
EPS	74	9-Jul	30	N. of Williams Island	0930	19.5	14.2	<1.8	<1.8					
EPS	74	9-Jul	30	N. of Williams Island	1440	18.0	15.3	7.8	2.0					
EPS	74	11-Jul	30	N. of Williams Island	1035	17.0	15.3	17.0	2.0					
EPS	74	11-Jul	30	N. of Williams Island	1405	18.0	14.2	<1.8	<1.8					
EPS	74	12-Jul	30	N. of Williams Island	1020	17.0	15.3	22.0	2.0					
EPS	74	15-Jul	30	N. of Williams Island	1445	17.0	16.5	33.0	2.0					
EPS	74	17-Jul	30	N. of Williams Island	0940	15.5	24.3	4.5	2.0					
EPS	74	17-Jul	30	N. of Williams Island	1615	16.5	14.2	7.8	<1.8					
EPS	74	19-Jul	30	N. of Williams Island	1020	17.0	14.2	70.0	17.0	7.8	2.4	2.0	0.0	0.0
EPS	74	4-Jul	33	S. end of Calder Island	1445	16.5	21.9	4.5	<1.8					
EPS	74	9-Jul	33	S. end of Calder Island	0925	20.0	14.7	23.0	2.0					
EPS	74	9-Jul	33	S. end of Calder Island	1445	18.0	15.3	130.0	17.0					
EPS	74	11-Jul	33	S. end of Calder Island	0955	17.0	15.3	23.0	2.0					
EPS	74	11-Jul	33	S. end of Calder Island	1420	18.0	14.7	49.0	4.5					
EPS	74	12-Jul	33	S. end of Calder Island	0945	17.0	14.7	33.0	4.5					
EPS	74	15-Jul	33	S. end of Calder Island	1410	18.0	16.5	70.0	2.0					
EPS	74	17-Jul	33	S. end of Calder Island	1005	16.0	14.7	49.0	17.0					
EPS	74	17-Jul	33	S. end of Calder Island	1340	17.0	14.2	49.0	2.0					
EPS	74	18-Jul	33	S. end of Calder Island	1430	18.0	14.2	49.0	<1.8	49.0	3.5	2.0	0.0	0.0
EPS	74	4-Jul	35	Entrance to Gerran's Bay	1445	17.0	20.8	170.0	2.0					
EPS	74	9-Jul	35	Entrance to Gerran's Bay	0925	18.0	15.3	12.0	2.0					
EPS	74	9-Jul	35	Entrance to Gerran's Bay	1445	18.0	15.9	540.0	1.8					
EPS	74	10-Jul	35	Entrance to Gerran's Bay	1435	18.0	13.5	920.0	4.5					
EPS	74	11-Jul	35	Entrance to Gerran's Bay	0945	17.5	15.3	79.0	6.8					
EPS	74	11-Jul	35	Entrance to Gerran's Bay	1420	18.0	14.7	540.0	2.0					
EPS	74	12-Jul	35	Entrance to Gerran's Bay	0945	17.5	14.7	240.0	23.0					
EPS	74	15-Jul	35	Entrance to Gerran's Bay	1405	18.0	18.0	170.0	6.8					
EPS	74	16-Jul	35	Entrance to Gerran's Bay	1330	17.0	15.3	540.0	<1.8					
EPS	74	17-Jul	35	Entrance to Gerran's Bay	1010	16.0	14.7	540.0	23.0					
EPS	74	17-Jul	35	Entrance to Gerran's Bay	1345	17.5	14.7	110.0	31.0					
EPS	74	18-Jul	35	Entrance to Gerran's Bay	0935	16.5	13.5	23.0	4.5					
EPS	74	18-Jul	35	Entrance to Gerran's Bay	1430	18.0	13.5	>1600	4.5					
EPS	74	19-Jul	35	Entrance to Gerran's Bay	0955	17.0	14.2	41.0	17.0	205.0	5.6	4.5	0.0	0.0
EPS	74	11-Jul	37	Head of Gerran's Bay	0940	17.5	14.7	140.0	21.0					
EPS	74	11-Jul	37	Head of Gerran's Bay	1425	18.0	14.7	49.0	14.0					
EPS	74	12-Jul	37	Head of Gerran's Bay	0940	17.0	14.2	920.0	920.0					
EPS	74	15-Jul	37	Head of Gerran's Bay	1400	18.0	17.3	17.0	<1.8					
EPS	74	16-Jul	37	Head of Gerran's Bay	0905	17.0	14.7	31.0	13.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
EPS	74	16-Jul	37	Head of Gerran's Bay	1335	17.5	15.9	7.8	7.8					
EPS	74	17-Jul	37	Head of Gerran's Bay	1015	16.5	14.2	540.0	240.0					
EPS	74	17-Jul	37	Head of Gerran's Bay	1350	17.0	14.7	7.8	7.8					
EPS	74	18-Jul	37	Head of Gerran's Bay	0935	17.0	13.5	14.0	14.0					
EPS	74	18-Jul	37	Head of Gerran's Bay	1435	18.0	13.5	49.0	13.0					
EPS	74	19-Jul	37	Head of Gerran's Bay	1000	17.5	14.2	110.0	70.0					
EPS	74	19-Jul	37	Head of Gerran's Bay	1430	17.5	14.7	33.0	33.0	41.0	24.1	14.0	25.0	8.3
EPS	74	17-Jul	38	N. entrance to Bargain N.	1020	16.0	14.7	240.0	79.0					
EPS	74	17-Jul	38	N. entrance to Bargain N.	1355	17.0	14.7	33.0	2.0					
EPS	74	18-Jul	38	N. entrance to Bargain N.	0925	16.5	13.5	170.0	130.0					
EPS	74	18-Jul	38	N. entrance to Bargain N.	1450	19.0	13.5	79.0	13.0					
EPS	74	19-Jul	38	N. entrance to Bargain N.	0950	18.0	13.5	110.0	33.0					
EPS	74	19-Jul	38	N. entrance to Bargain N.	1445	19.0	14.2	110.0	79.0	110.0	29.8	56.0	50.0	0.0
EPS	74	11-Jul	41	South of Garden Peninsula	1000	17.0	15.3	240.0	<1.8					
EPS	74	11-Jul	41	South of Garden Peninsula	1545	17.5	14.7	110.0	2.0					
EPS	74	12-Jul	41	South of Garden Peninsula	0950	17.0	14.7	49.0	7.8					
EPS	74	15-Jul	41	South of Garden Peninsula	1415	18.0	15.9	13.0	4.5					
EPS	74	16-Jul	41	South of Garden Peninsula	1430	16.5	15.9	11.0	4.5					
EPS	74	17-Jul	41	South of Garden Peninsula	1025	16.0	14.7	33.0	11.0					
EPS	74	17-Jul	41	South of Garden Peninsula	1530	16.5	14.2	2.0	<1.8					
EPS	74	18-Jul	41	South of Garden Peninsula	0920	16.5	13.5	70.0	46.0					
EPS	74	18-Jul	41	South of Garden Peninsula	1500	17.5	14.2	33.0	<1.8					
EPS	74	19-Jul	41	South of Garden Peninsula	1010	17.0	14.2	33.0	4.5					
EPS	74	19-Jul	41	South of Garden Peninsula	1425	17.5	14.2	46.0	13.0	33.0	5.1	4.5	9.1	0.0
EPS	74	11-Jul	43	SE of entrance to Gunboat	1105	17.0	15.3	46.0	<1.8					
EPS	74	11-Jul	43	SE of entrance to Gunboat	1550	18.0	15.3	350.0	6.8					
EPS	74	12-Jul	43	SE of entrance to Gunboat	0955	17.0	15.3	32.0	4.0					
EPS	74	15-Jul	43	SE of entrance to Gunboat	1420	17.5	16.5	23.0	2.0					
EPS	74	16-Jul	43	SE of entrance to Gunboat	0900	17.0	24.3	13.0	<1.8					
EPS	74	16-Jul	43	SE of entrance to Gunboat	1430	17.0	15.9	110.0	4.5					
EPS	74	17-Jul	43	SE of entrance to Gunboat	1050	17.0	15.9	79.0	27.0					
EPS	74	17-Jul	43	SE of entrance to Gunboat	1545	17.0	14.7	17.0	4.5					
EPS	74	18-Jul	43	SE of entrance to Gunboat	0910	16.5	14.2	46.0	7.8					
EPS	74	18-Jul	43	SE of entrance to Gunboat	1500	17.5	14.2	49.0	2.0					
EPS	74	19-Jul	43	SE of entrance to Gunboat	1420	17.5	14.2	17.0	6.8	46.0	4.3	4.5	0.0	0.0
EPS	74	3-Jul	44	SE tip of Francis Penin.	1510	15.0	21.9	49.0	11.0					
EPS	74	4-Jul	44	SE tip of Francis Penin.	1115	15.0	21.9	23.0	2.0					
EPS	74	4-Jul	44	SE tip of Francis Penin.	1540	19.5	21.9	27.0	4.5					
EPS	74	9-Jul	44	SE tip of Francis Penin.	0955	19.5	13.5	11.0	<1.8					
EPS	74	9-Jul	44	SE tip of Francis Penin.	1345	17.5	14.2	130.0	130.0					
EPS	74	11-Jul	44	SE tip of Francis Penin.	0930	16.5	14.7	6.8	1.8					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDIN 400/100 mL
EPS	74	11-Jul	44	SE tip of Francis Penin.	1520	17.0	15.3	33.0	13.0					
EPS	74	12-Jul	44	SE tip of Francis Penin.	0915	16.5	14.7	23.0	7.8					
EPS	74	15-Jul	44	SE tip of Francis Penin.	1345	17.0	15.3	<1.8	<1.8					
EPS	74	16-Jul	44	SE tip of Francis Penin.	1355	17.0	15.3	49.0	33.0					
EPS	74	18-Jul	44	SE tip of Francis Penin.	1415	19.0	13.0	23.0	4.5	23.0	6.7	4.5	9.1	0.0
EPS	74	3-Jul	45	Bargain Bay	1440	15.0	20.8	33.0	13.0					
EPS	74	4-Jul	45	Bargain Bay	1045	15.0	20.8	14.0	4.5					
EPS	74	4-Jul	45	Bargain Bay	1510	17.0	21.9	7.8	4.5					
EPS	74	9-Jul	45	Bargain Bay	1010	17.5	14.7	4.5	4.5					
EPS	74	9-Jul	45	Bargain Bay	1350	18.0	14.2	23.0	13.0					
EPS	74	11-Jul	45	Bargain Bay	0850	16.5	13.5	130.0	4.5					
EPS	74	11-Jul	45	Bargain Bay	1445	18.0	14.7	17.0	4.0					
EPS	74	12-Jul	45	Bargain Bay	0920	16.5	14.2	170.0	49.0					
EPS	74	15-Jul	45	Bargain Bay	1350	18.0	16.5	11.0	11.0					
EPS	74	16-Jul	45	Bargain Bay	1350	17.5	15.3	11.0	1.8					
EPS	74	17-Jul	45	Bargain Bay	1410	17.0	13.0	9.3	2.0	14.0	6.2	4.5	9.1	0.0
EPS	74	3-Jul	48	Head of Bargain Bay	1435	15.0	20.8	4.0	<1.8					
EPS	74	4-Jul	48	Head of Bargain Bay	1040	15.0	20.8	17.0	2.0					
EPS	74	4-Jul	48	Head of Bargain Bay	1505	17.0	21.9	7.8	2.0					
EPS	74	9-Jul	48	Head of Bargain Bay	1000	18.0	14.7	6.8	<1.8					
EPS	74	9-Jul	48	Head of Bargain Bay	1350	18.0	13.5	79.0	22.0					
EPS	74	11-Jul	48	Head of Bargain Bay	0845	17.0	13.5	49.0	7.8					
EPS	74	11-Jul	48	Head of Bargain Bay	1445	18.0	14.7	33.0	11.0					
EPS	74	12-Jul	48	Head of Bargain Bay	0925	17.0	14.7	14.0	2.0					
EPS	74	15-Jul	48	Head of Bargain Bay	1355	18.0	17.3	49.0	49.0					
EPS	74	16-Jul	48	Head of Bargain Bay	1345	17.0	15.3	7.8	4.5	15.5	5.1	3.3	10.0	0.0
EPS	74	3-Jul	52	N. of Edgecombe Island	1450	15.5	20.8	17.0	4.5					
EPS	74	4-Jul	52	N. of Edgecombe Island	1055	15.0	20.8	6.8	2.0					
EPS	74	4-Jul	52	N. of Edgecombe Island	1515	16.5	19.9	11.0	<1.8					
EPS	74	5-Jul	52	N. of Edgecombe Island	1330	17.5	18.0	13.0	<1.8					
EPS	74	8-Jul	52	N. of Edgecombe Island	1400	18.0	14.2	130.0	<1.8					
EPS	74	9-Jul	52	N. of Edgecombe Island	1015	18.0	14.2	11.0	<1.8					
EPS	74	9-Jul	52	N. of Edgecombe Island	1400	18.0	14.2	33.0	2.0					
EPS	74	10-Jul	52	N. of Edgecombe Island	1355	17.0	13.5	43.0	2.0					
EPS	74	11-Jul	52	N. of Edgecombe Island	0855	16.5	14.2	23.0	2.0					
EPS	74	11-Jul	52	N. of Edgecombe Island	1450	17.0	14.7	7.8	<1.8	15.0	2.1	1.9	0.0	0.0
EPS	74	3-Jul	53	NE. of Edgecombe Island	1445	15.0	20.8	33.0	4.5					
EPS	74	4-Jul	53	NE. of Edgecombe Island	1055	15.0	20.8	11.0	2.0					
EPS	74	4-Jul	53	NE. of Edgecombe Island	1520	17.0	20.8	4.5	2.0					
EPS	74	5-Jul	53	NE. of Edgecombe Island	1335	17.5	18.0	13.0	<1.8					
EPS	74	8-Jul	53	NE. of Edgecombe Island	1405	18.0	14.2	7.9	1.8					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION	STATION LOCATION	TIME	TEMP	SAL	TOTAL COLIF	FECAL COLIF	TOTAL	FECAL	FECAL	% EXCEEDING	% EXCEEDIN
			NUMBER			(°C)	(ppt)	(MPN/100 mL)	(MPN/100 mL)	MEDIAN	GEO. MEAN	MEDIAN	43/100 mL	400/100 mL
EPS	74	9-Jul	53	NE. of Edgecombe Island	1015	20.0	13.5	4.5	<1.8					
EPS	74	9-Jul	53	NE. of Edgecombe Island	1400	18.0	14.2	4.5	2.0					
EPS	74	10-Jul	53	NE. of Edgecombe Island	1400	17.0	13.5	33.0	11.0					
EPS	74	11-Jul	53	NE. of Edgecombe Island	0900	16.5	14.7	7.8	2.0					
EPS	74	11-Jul	53	NE. of Edgecombe Island	1455	17.5	14.7	46.0	7.8	9.5	2.9	2.0	0.0	0.0
EPS	74	17-Jul	S2	Stream into E. Pender Bay	1730			1300.0	490.0					
EPS	74	18-Jul	S2	Stream into E. Pender Bay	1600			700.0	700.0					
EPS	74	19-Jul	S2	Stream into E. Pender Bay	1200			1300.0	790.0					
EPS	74	19-Jul	S2	Stream into E. Pender Bay	1530			1100.0	230.0	1200.0	499.6	595.0	100.0	75.0
MOE	77	8-Aug	3	Entrance to E. Pender Bay	1340			<2	<2					
MOE	77	10-Aug	3	Entrance to E. Pender Bay	0910			2.0	2.0					
MOE	77	15-Aug	3	Entrance to E. Pender Bay	1255	21.5	25.0	11.0	11.0					
MOE	77	17-Aug	3	Entrance to E. Pender Bay	0945	20.0	24.0	5.0	<2					
MOE	77	22-Aug	3	Entrance to E. Pender Bay	1310			9.0	<2					
MOE	77	24-Aug	3	Entrance to E. Pender Bay	0920			17.0	11.0					
MOE	77	29-Aug	3	Entrance to E. Pender Bay	1320	20.5	20.5	49.0	13.0					
MOE	77	31-Aug	3	Entrance to E. Pender Bay	1015	20.0	21.0	11.0	8.0					
MOE	77	7-Sep	3	Entrance to E. Pender Bay	1020	18.0	22.0	11.0	5.0					
MOE	77	12-Sep	3	Entrance to E. Pender Bay	1320	17.0	24.0	23.0	5.0					
MOE	77	14-Sep	3	Entrance to E. Pender Bay	1135	15.0	25.0	13.0	8.0					
MOE	77	19-Sep	3	Entrance to E. Pender Bay	1315	14.0	24.0	79.0	79.0					
MOE	77	21-Sep	3	Entrance to E. Pender Bay	1010	14.5	22.5	49.0	13.0					
MOE	77	26-Sep	3	Entrance to E. Pender Bay	1350	14.0	22.5	6.0	2.0					
MOE	77	28-Sep	3	Entrance to E. Pender Bay	0919	12.5	22.8	14.0	8.0	11.0	6.1	8.0	6.7	0.0
MOE	77	8-Aug	4	S. Oyster Bay	1350			<2	<2					
MOE	77	10-Aug	4	S. Oyster Bay	0915			31.0	11.0					
MOE	77	15-Aug	4	S. Oyster Bay	1305	20.0	25.0	2.0	<2					
MOE	77	17-Aug	4	S. Oyster Bay	0950	22.0	24.0	7.0	4.0					
MOE	77	22-Aug	4	S. Oyster Bay	1317			11.0	2.0					
MOE	77	24-Aug	4	S. Oyster Bay	0925			8.0	8.0					
MOE	77	29-Aug	4	S. Oyster Bay	1325	19.5	20.0	70.0	13.0					
MOE	77	31-Aug	4	S. Oyster Bay	1020	20.0	21.0	5.0	<2					
MOE	77	7-Sep	4	S. Oyster Bay	1025	18.0	22.5	23.0	5.0					
MOE	77	12-Sep	4	S. Oyster Bay	1325	16.0	24.5	8.0	5.0					
MOE	77	14-Sep	4	S. Oyster Bay	1140	15.0	25.0	18.0	8.0					
MOE	77	19-Sep	4	S. Oyster Bay	1325	13.5	20.0	8.0	2.0					
MOE	77	21-Sep	4	S. Oyster Bay	1020	14.0	22.5	170.0	14.0					
MOE	77	26-Sep	4	S. Oyster Bay	1355	14.0	23.0	13.0	5.0					
MOE	77	28-Sep	4	S. Oyster Bay	0915	13.0	23.1	5.0	2.0	8.0	4.4	5.0	0.0	0.0
MOE	77	8-Aug	19	Entrance to Gunboat Bay	1405			4.0	<2					
MOE	77	10-Aug	19	Entrance to Gunboat Bay	0925			5.0	2.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDIN 43/100 mL	% EXCEEDIN 400/100 mL
MOE	77	15-Aug	19	Entrance to Gunboat Bay	1315	19.5	24.0	2.0	<2					
MOE	77	17-Aug	19	Entrance to Gunboat Bay	1005	22.0	23.5	8.0	<2					
MOE	77	22-Aug	19	Entrance to Gunboat Bay	1330			17.0	2.0					
MOE	77	24-Aug	19	Entrance to Gunboat Bay	0935			11.0	8.0					
MOE	77	29-Aug	19	Entrance to Gunboat Bay	1335	19.5	21.0	31.0	4.0					
MOE	77	31-Aug	19	Entrance to Gunboat Bay	1025	19.5	22.0	2.0	2.0					
MOE	77	7-Sep	19	Entrance to Gunboat Bay	1035	16.5	21.0	2.0	<2					
MOE	77	12-Sep	19	Entrance to Gunboat Bay	1330	15.0	25.5	<2	<2					
MOE	77	14-Sep	19	Entrance to Gunboat Bay	1145	13.5	26.0	8.0	2.0					
MOE	77	19-Sep	19	Entrance to Gunboat Bay	1335	14.0	20.0	8.0	2.0					
MOE	77	21-Sep	19	Entrance to Gunboat Bay	1030	14.0	22.0	11.0	4.0					
MOE	77	26-Sep	19	Entrance to Gunboat Bay	1400	13.5	24.5	2.0	2.0					
MOE	77	28-Sep	19	Entrance to Gunboat Bay	0925	12.9	23.9	5.0	2.0	5.0	2.4	2.0	0.0	0.0
MOE	77	8-Aug	21	S. E. Garden Bay	1615			<2	<2					
MOE	77	10-Aug	21	S. E. Garden Bay	1045			13.0	2.0					
MOE	77	15-Aug	21	S. E. Garden Bay	1450		24.0	<2	<2					
MOE	77	17-Aug	21	S. E. Garden Bay	1145	20.0	24.5	79.0	5.0					
MOE	77	22-Aug	21	S. E. Garden Bay	1505			8.0	5.0					
MOE	77	24-Aug	21	S. E. Garden Bay	1055			11.0	2.0					
MOE	77	29-Aug	21	S. E. Garden Bay	1505	18.0	20.5	23.0	13.0					
MOE	77	31-Aug	21	S. E. Garden Bay	1205	20.5	21.0	27.0	2.0					
MOE	77	7-Sep	21	S. E. Garden Bay	1205	17.0	23.5	2.0	2.0					
MOE	77	12-Sep	21	S. E. Garden Bay	1455	16.5	23.0	14.0	2.0					
MOE	77	14-Sep	21	S. E. Garden Bay	1120	14.5	26.0	23.0	5.0					
MOE	77	19-Sep	21	S. E. Garden Bay	1510	14.0	25.0	79.0	14.0					
MOE	77	21-Sep	21	S. E. Garden Bay	1235	14.0	24.0	8.0	5.0					
MOE	77	26-Sep	21	S. E. Garden Bay	1550	14.0	24.0	23.0	2.0					
MOE	77	28-Sep	21	S. E. Garden Bay	1055	13.0	24.2	13.0	5.0	13.0	3.5	2.0	0.0	0.0
MOE	77	8-Aug	23	N. W. Garden Bay	1600			22.0	4.0					
MOE	77	10-Aug	23	N. W. Garden Bay	1035			49.0	<2					
MOE	77	15-Aug	23	N. W. Garden Bay	1440	20.0	24.5	49.0	<2					
MOE	77	17-Aug	23	N. W. Garden Bay	1135	20.0	24.5	350.0	27.0					
MOE	77	22-Aug	23	N. W. Garden Bay	1455			79.0	5.0					
MOE	77	24-Aug	23	N. W. Garden Bay	1045			13.0	8.0					
MOE	77	29-Aug	23	N. W. Garden Bay	1455	19.0	20.0	79.0	13.0					
MOE	77	31-Aug	23	N. W. Garden Bay	1155	20.0	21.0	79.0	4.0					
MOE	77	7-Sep	23	N. W. Garden Bay	1155	17.0	22.0	23.0	2.0					
MOE	77	12-Sep	23	N. W. Garden Bay	1440	17.0	25.0	13.0	8.0					
MOE	77	14-Sep	23	N. W. Garden Bay	1110	14.0	26.0	8.0	5.0					
MOE	77	19-Sep	23	N. W. Garden Bay	1505	14.0	25.0	79.0	79.0					
MOE	77	21-Sep	23	N. W. Garden Bay	1230	14.0	23.0	23.0	2.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDIN 400/100 mL
MOE	77	26-Sep	23	N. W. Garden Bay	1540	14.0	24.5	8.0	<2					
MOE	77	28-Sep	23	N. W. Garden Bay	1045	13.0	24.2	240.0	240.0	49.0	7.1	5.0	13.3	0.0
MOE	77	8-Aug	25	S. E. Hospital Bay	1550			33.0	2.0					
MOE	77	10-Aug	25	S. E. Hospital Bay	1025			49.0	4.0					
MOE	77	15-Aug	25	S. E. Hospital Bay	1425	21.0	24.0	220.0	7.0					
MOE	77	17-Aug	25	S. E. Hospital Bay	1125	18.5	26.0	170.0	79.0					
MOE	77	22-Aug	25	S. E. Hospital Bay	1445			11.0	5.0					
MOE	77	24-Aug	25	S. E. Hospital Bay	1035			540.0	49.0					
MOE	77	29-Aug	25	S. E. Hospital Bay	1445	21.0	20.0	33.0	<2					
MOE	77	31-Aug	25	S. E. Hospital Bay	1145	20.0	22.0	5.0	2.0					
MOE	77	7-Sep	25	S. E. Hospital Bay	1150	17.0	22.5	33.0	2.0					
MOE	77	12-Sep	25	S. E. Hospital Bay	1440	17.0	25.0	17.0	17.0					
MOE	77	14-Sep	25	S. E. Hospital Bay	1100	14.0	26.0	31.0	23.0					
MOE	77	19-Sep	25	S. E. Hospital Bay	1455	14.0	25.5	17.0	4.0					
MOE	77	21-Sep	25	S. E. Hospital Bay	1220	14.5	23.0	11.0	<2					
MOE	77	26-Sep	25	S. E. Hospital Bay	1535	14.0	25.0	2.0	<2					
MOE	77	28-Sep	25	S. E. Hospital Bay	1030	13.0	24.4	33.0	23.0	33.0	6.4	4.0	13.3	0.0
MOE	77	8-Aug	28	N. W. Hospital Bay	1540			2.0	<2					
MOE	77	10-Aug	28	N. W. Hospital Bay	1020			8.0	<2					
MOE	77	15-Aug	28	N. W. Hospital Bay	1420	21.0	24.0	5.0	<2					
MOE	77	17-Aug	28	N. W. Hospital Bay	1120	20.0	24.5	79.0	8.0					
MOE	77	22-Aug	28	N. W. Hospital Bay	1440			46.0	33.0					
MOE	77	24-Aug	28	N. W. Hospital Bay	1030			34.0	11.0					
MOE	77	29-Aug	28	N. W. Hospital Bay	1435	21.0	20.0	8.0	2.0					
MOE	77	31-Aug	28	N. W. Hospital Bay	1140	20.0	21.0	170.0	8.0					
MOE	77	7-Sep	28	N. W. Hospital Bay	1140	17.0	23.0	9.0	6.0					
MOE	77	12-Sep	28	N. W. Hospital Bay	1435	17.0	25.0	4.0	<2					
MOE	77	14-Sep	28	N. W. Hospital Bay	1050	14.0	25.5	33.0	33.0					
MOE	77	19-Sep	28	N. W. Hospital Bay	1450	14.0	25.0	94.0	94.0					
MOE	77	21-Sep	28	N. W. Hospital Bay	1215	14.5	23.0	33.0	8.0					
MOE	77	26-Sep	28	N. W. Hospital Bay	1530	14.0	24.5	5.0	2.0					
MOE	77	28-Sep	28	N. W. Hospital Bay	1025	13.0	24.2	2.0	<2	9.0	6.0	6.0	6.7	0.0
MOE	77	8-Aug	29	Duncan Cove	1530			<2	<2					
MOE	77	10-Aug	29	Duncan Cove	1015			2.0	<2					
MOE	77	15-Aug	29	Duncan Cove	1410	20.5	24.5	<2	<2					
MOE	77	17-Aug	29	Duncan Cove	1110	20.0	24.5	49.0	2.0					
MOE	77	22-Aug	29	Duncan Cove	1435			7.0	4.0					
MOE	77	24-Aug	29	Duncan Cove	1025			13.0	5.0					
MOE	77	29-Aug	29	Duncan Cove	1425	21.5	20.5	49.0	<2					
MOE	77	31-Aug	29	Duncan Cove	1135	20.0	21.0	17.0	<2					
MOE	77	7-Sep	29	Duncan Cove	1130	17.0	24.0	23.0	23.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
MOE	77	12-Sep	29	Duncan Cove	1430	15.5	25.5	2.0	<2					
MOE	77	14-Sep	29	Duncan Cove	1040	13.5	21.5	27.0	5.0					
MOE	77	19-Sep	29	Duncan Cove	1440	14.0	25.0	110.0	13.0					
MOE	77	21-Sep	29	Duncan Cove	1210	14.5	24.0	33.0	5.0					
MOE	77	26-Sep	29	Duncan Cove	1515	14.0	24.5	<2	<2					
MOE	77	28-Sep	29	Duncan Cove	1015	13.0	23.8	33.0	<2	17.0	3.4	2.0	0.0	0.0
MOE	77	8-Aug	31	Donnely Landing	1520			<2	<2					
MOE	77	10-Aug	31	Donnely Landing	1010			23.0	13.0					
MOE	77	15-Aug	31	Donnely Landing	1405	20.0	24.0	<2	<2					
MOE	77	17-Aug	31	Donnely Landing	1105	20.0	24.5	110.0	79.0					
MOE	77	22-Aug	31	Donnely Landing	1430			2.0	<2					
MOE	77	24-Aug	31	Donnely Landing	1020			23.0	5.0					
MOE	77	29-Aug	31	Donnely Landing	1415	20.0	20.5	8.0	8.0					
MOE	77	31-Aug	31	Donnely Landing	1130	20.5	21.0	13.0	13.0					
MOE	77	7-Sep	31	Donnely Landing	1125	17.0	24.0	2.0	2.0					
MOE	77	12-Sep	31	Donnely Landing	1420	15.0	25.5	23.0	2.0					
MOE	77	14-Sep	31	Donnely Landing	1030	13.0	26.5	5.0	<2					
MOE	77	19-Sep	31	Donnely Landing	1430	14.0	25.0	33.0	17.0					
MOE	77	21-Sep	31	Donnely Landing	1200	14.5	23.5	2.0	2.0					
MOE	77	26-Sep	31	Donnely Landing	1510	14.0	23.5	2.0	<2					
MOE	77	28-Sep	31	Donnely Landing	1010	13.0	24.4	33.0	2.0	8.0	4.4	2.0	6.7	0.0
MOE	77	8-Aug	32	N. end of Calder Ch.	1515			2.0	<2					
MOE	77	10-Aug	32	N. end of Calder Ch.	1005			2.0	2.0					
MOE	77	15-Aug	32	N. end of Calder Ch.	1400	20.0	24.0	2.0	2.0					
MOE	77	17-Aug	32	N. end of Calder Ch.	1100	21.0	24.0	5.0	2.0					
MOE	77	22-Aug	32	N. end of Calder Ch.	1420			33.0	7.0					
MOE	77	24-Aug	32	N. end of Calder Ch.	1015			8.0	5.0					
MOE	77	29-Aug	32	N. end of Calder Ch.	1410	20.0	20.5	5.0	<2					
MOE	77	31-Aug	32	N. end of Calder Ch.	1125	20.0	21.5	2.0	<2					
MOE	77	7-Sep	32	N. end of Calder Ch.	1110	17.0	22.0	79.0	33.0					
MOE	77	12-Sep	32	N. end of Calder Ch.	1415	16.5	25.0	4.0	2.0					
MOE	77	14-Sep	32	N. end of Calder Ch.	1025	13.5	26.0	17.0	5.0					
MOE	77	19-Sep	32	N. end of Calder Ch.	1425	14.0	24.5	23.0	8.0					
MOE	77	21-Sep	32	N. end of Calder Ch.	1150	14.0	24.5	<2	<2					
MOE	77	26-Sep	32	N. end of Calder Ch.	1505	14.0	24.0	5.0	2.0					
MOE	77	28-Sep	32	N. end of Calder Ch.	1005	13.0	23.9	46.0	5.0	5.0	3.5	2.0	0.0	0.0
MOE	77	8-Aug	34	N.W. Gerrans Bay	1510			<2	<2					
MOE	77	10-Aug	34	N.W. Gerrans Bay	1000			5.0	<2					
MOE	77	15-Aug	34	N.W. Gerrans Bay	1355	20.0	24.0	17.0	<2					
MOE	77	17-Aug	34	N.W. Gerrans Bay	1055	24.0	24.0	<2	<2					
MOE	77	22-Aug	34	N.W. Gerrans Bay	1415			8.0	2.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDIN 43/100 mL	% EXCEEDIN 400/100 mL
MOE	77	24-Aug	34	N.W. Gerrans Bay	1005			9.0	2.0					
MOE	77	29-Aug	34	N.W. Gerrans Bay	1405	20.0	21.0	5.0	<2					
MOE	77	31-Aug	34	N.W. Gerrans Bay	1120	20.0	21.0	2.0	2.0					
MOE	77	7-Sep	34	N.W. Gerrans Bay	1110	17.0	23.0	2.0	<2					
MOE	77	12-Sep	34	N.W. Gerrans Bay	1410	16.5	25.0	<2	<2					
MOE	77	14-Sep	34	N.W. Gerrans Bay	1020	13.5	26.0	7.0	2.0					
MOE	77	19-Sep	34	N.W. Gerrans Bay	1420	14.0	24.5	8.0	2.0					
MOE	77	21-Sep	34	N.W. Gerrans Bay	1140	14.0	24.5	5.0	<2					
MOE	77	26-Sep	34	N.W. Gerrans Bay	1500	14.5	23.5	23.0	<2					
MOE	77	28-Sep	34	N.W. Gerrans Bay	1000	13.0	23.9	23.0	<2	5.0	2.0	2.0	0.0	0.0
MOE	77	8-Aug	36	S. Gerrans Bay	1500			5.0	<2					
MOE	77	10-Aug	36	S. Gerrans Bay	0950			46.0	11.0					
MOE	77	15-Aug	36	S. Gerrans Bay	1345	20.0	24.5	<2	<2					
MOE	77	17-Aug	36	S. Gerrans Bay	1045	20.0	24.0	33.0	5.0					
MOE	77	22-Aug	36	S. Gerrans Bay	1410			<2	<2					
MOE	77	24-Aug	36	S. Gerrans Bay	1000			17.0	2.0					
MOE	77	29-Aug	36	S. Gerrans Bay	1400	20.0	20.5	5.0	<2					
MOE	77	31-Aug	36	S. Gerrans Bay	1110	21.0	21.0	5.0	<2					
MOE	77	7-Sep	36	S. Gerrans Bay	1100	17.0	23.0	23.0	<2					
MOE	77	12-Sep	36	S. Gerrans Bay	1400	16.5	24.5	13.0	2.0					
MOE	77	14-Sep	36	S. Gerrans Bay	1015	13.5	26.0	13.0	8.0					
MOE	77	19-Sep	36	S. Gerrans Bay	1410	14.5	24.0	2.0	2.0					
MOE	77	21-Sep	36	S. Gerrans Bay	1135	14.0	24.0	5.0	<2					
MOE	77	26-Sep	36	S. Gerrans Bay	1445	14.5	24.5	<2	<2					
MOE	77	28-Sep	36	S. Gerrans Bay	0950	13.0	24.2	13.0	2.0	5.0	2.6	2.0	0.0	0.0
MOE	77	8-Aug	40	Coho narrows	1445			<2	<2					
MOE	77	10-Aug	40	Coho narrows	0940			8.0	5.0					
MOE	77	15-Aug	40	Coho narrows	1335	20.0	25.0	<2	<2					
MOE	77	17-Aug	40	Coho narrows	1020	22.5	24.0	5.0	2.0					
MOE	77	22-Aug	40	Coho narrows	1350			5.0	<2					
MOE	77	24-Aug	40	Coho narrows	0945			8.0	8.0					
MOE	77	29-Aug	40	Coho narrows	1350	18.0	21.5	2.0	<2					
MOE	77	31-Aug	40	Coho narrows	1040	20.0	21.0	4.0	4.0					
MOE	77	7-Sep	40	Coho narrows	1050	17.0	24.0	2.0	<2					
MOE	77	12-Sep	40	Coho narrows	1350	16.0	25.0	<2	<2					
MOE	77	14-Sep	40	Coho narrows	1010	14.0	26.0	8.0	5.0					
MOE	77	19-Sep	40	Coho narrows	1350	14.0	22.0	13.0	8.0					
MOE	77	21-Sep	40	Coho narrows	1045	14.0	23.5	5.0	2.0					
MOE	77	26-Sep	40	Coho narrows	1420	14.0	22.5	<2	<2					
MOE	77	28-Sep	40	Coho narrows	0940	13.0	23.9	49.0	22.0	5.0	3.3	2.0	0.0	0.0
MOE	77	8-Aug	42	Entrance to Welbourn Cove	1430			2.0	<2					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
MOE	77	10-Aug	42	Entrance to Welbourn Cove	0930			5.0	<2					
MOE	77	15-Aug	42	Entrance to Welbourn Cove	1320	20.0	24.0	2.0	2.0					
MOE	77	17-Aug	42	Entrance to Welbourn Cove	1010	22.0	23.0	23.0	5.0					
MOE	77	22-Aug	42	Entrance to Welbourn Cove	1335			11.0	2.0					
MOE	77	24-Aug	42	Entrance to Welbourn Cove	0940			7.0	7.0					
MOE	77	29-Aug	42	Entrance to Welbourn Cove	1340	18.0	21.0	79.0	<2					
MOE	77	31-Aug	42	Entrance to Welbourn Cove	1030	19.5	22.0	79.0	79.0					
MOE	77	7-Sep	42	Entrance to Welbourn Cove	1040	17.0	23.5	2.0	<2					
MOE	77	12-Sep	42	Entrance to Welbourn Cove	1340	15.5	25.5	2.0	2.0					
MOE	77	14-Sep	42	Entrance to Welbourn Cove	1150	13.5	26.5	79.0	23.0					
MOE	77	29-Sep	42	Entrance to Welbourn Cove	1335	14.0	22.5	33.0	33.0					
MOE	77	21-Sep	42	Entrance to Welbourn Cove	1035	14.0	24.0	2.0	2.0					
MOE	77	26-Sep	42	Entrance to Welbourn Cove	1405	14.0	24.5	11.0	2.0					
MOE	77	28-Sep	42	Entrance to Welbourn Cove	0930	13.0	23.9	2.0	<2	7.0	4.2	2.0	6.7	0.0
MOE	77	8-Aug	50	E. side of Bargain Bay	1630			7.0	<2					
MOE	77	10-Aug	50	E. side of Bargain Bay	1130			2.0	<2					
MOE	77	15-Aug	50	E. side of Bargain Bay	1320	21.5	23.0	<2	<2					
MOE	77	17-Aug	50	E. side of Bargain Bay	1220	20.0	25.0	5.0	2.0					
MOE	77	22-Aug	50	E. side of Bargain Bay	1400			<2	<2					
MOE	77	24-Aug	50	E. side of Bargain Bay	1120			21.0	7.0					
MOE	77	29-Aug	50	E. side of Bargain Bay	1545	22.0	20.0	2.0	<2					
MOE	77	31-Aug	50	E. side of Bargain Bay	1100	19.5	21.0	2.0	<2					
MOE	77	7-Sep	50	E. side of Bargain Bay	1225	17.5	23.0	<2	<2					
MOE	77	12-Sep	50	E. side of Bargain Bay	1510	15.5	26.0	2.0	<2					
MOE	77	14-Sep	50	E. side of Bargain Bay	1005	13.0	27.0	17.0	2.0					
MOE	77	19-Sep	50	E. side of Bargain Bay	1355	14.0	24.0	2.0	2.0					
MOE	77	21-Sep	50	E. side of Bargain Bay	1115	14.0	23.5	2.0	<2					
MOE	77	26-Sep	50	E. side of Bargain Bay	1435	14.0	23.0	5.0	2.0					
MOE	77	28-Sep	50	E. side of Bargain Bay	1130	13.0	22.5	33.0	2.0	2.0	2.2	2.0	0.0	0.0
MOE	77	10-Aug	S5	Malaspina Creek	1210			79.0	49.0					
MOE	77	15-Aug	S5	Malaspina Creek	1600			46.0	46.0					
MOE	77	17-Aug	S5	Malaspina Creek	1310			240.0	23.0					
MOE	77	22-Aug	S5	Malaspina Creek	1605			920.0	920.0					
MOE	77	24-Aug	S5	Malaspina Creek	1135			540.0	110.0					
MOE	77	29-Aug	S5	Malaspina Creek	1600	18.0		540.0	49.0					
MOE	77	31-Aug	S5	Malaspina Creek	1235	17.0		540.0	110.0					
MOE	77	7-Sep	S5	Malaspina Creek	1355	14.0		540.0	33.0					
MOE	77	12-Sep	S5	Malaspina Creek	1545	15.5		130.0	14.0					
MOE	77	14-Sep	S5	Malaspina Creek	1230	13.5		240.0	5.0					
MOE	77	19-Sep	S5	Malaspina Creek	1535	13.5		1600.0	1600.0					
MOE	77	21-Sep	S5	Malaspina Creek	1300	12.5		540.0	350.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
MOE	77	26-Sep	S5	Malaspina Creek	1615	12.5		220.0	130.0					
MOE	77	28-Sep	S5	Malaspina Creek	1140			540.0	70.0	540.0	78.4	59.5	71.4	14.3
MOE	77	8-Aug	S10	Lower Anderson Creek	1705			540.0	540.0					
MOE	77	10-Aug	S10	Lower Anderson Creek	1155			>2400	1600.0					
MOE	77	15-Aug	S10	Lower Anderson Creek	1545			>2400	>2400					
MOE	77	17-Aug	S10	Lower Anderson Creek	1245			>2400	1600.0					
MOE	77	22-Aug	S10	Lower Anderson Creek	1545			1600.0	920.0					
MOE	77	24-Aug	S10	Lower Anderson Creek	1145			>2400	350.0					
MOE	77	29-Aug	S10	Lower Anderson Creek	1615	15.0		490.0	490.0					
MOE	77	31-Aug	S10	Lower Anderson Creek	1250	14.0		330.0	330.0					
MOE	77	7-Sep	S10	Lower Anderson Creek	1420	13.0		700.0	70.0					
MOE	77	12-Sep	S10	Lower Anderson Creek	1600	13.0		790.0	220.0					
MOE	77	14-Sep	S10	Lower Anderson Creek	1200	13.0		130.0	<20					
MOE	77	19-Sep	S10	Lower Anderson Creek	1555	12.0		2200.0	1700.0					
MOE	77	21-Sep	S10	Lower Anderson Creek	1315	11.0		170.0	50.0					
MOE	77	26-Sep	S10	Lower Anderson Creek	1625			20.0	20.0					
MOE	77	28-Sep	S10	Lower Anderson Creek	1150			<20	<20	700.0	261.3	350.0	80.0	46.7
MOE	77	8-Aug	S13	Upper Anderson Creek	1705			>2400	>2400					
MOE	77	10-Aug	S13	Upper Anderson Creek	1200			540.0	540.0					
MOE	77	15-Aug	S13	Upper Anderson Creek	1555			22.0	11.0					
MOE	77	17-Aug	S13	Upper Anderson Creek	1300			70.0	17.0					
MOE	77	22-Aug	S13	Upper Anderson Creek	1555			49.0	5.0					
MOE	77	24-Aug	S13	Upper Anderson Creek	1155			49.0	8.0					
MOE	77	29-Aug	S13	Upper Anderson Creek	1630	14.5		11.0	2.0					
MOE	77	31-Aug	S13	Upper Anderson Creek	1305	14.0		130.0	20.0					
MOE	77	7-Sep	S13	Upper Anderson Creek	1430	13.0		<20	<20					
MOE	77	12-Sep	S13	Upper Anderson Creek	1615	13.0		50.0	<20					
MOE	77	14-Sep	S13	Upper Anderson Creek	1310	13.0		<20	<20					
MOE	77	19-Sep	S13	Upper Anderson Creek	1605	12.0		220.0	50.0					
MOE	77	21-Sep	S13	Upper Anderson Creek	1325	11.0		70.0	40.0					
MOE	77	26-Sep	S13	Upper Anderson Creek	1635	11.0		20.0	<20					
MOE	77	28-Sep	S13	Upper Anderson Creek	1200	10.0		20.0	<20	49.0	26.7	20.0	20.0	13.3
MOE	77	8-Aug	S16	Lower Myers Creek	1700			>2400	110.0					
MOE	77	10-Aug	S16	Lower Myers Creek	1150			>2400	920.0					
MOE	77	15-Aug	S16	Lower Myers Creek	1540			>2400	>2400					
MOE	77	17-Aug	S16	Lower Myers Creek	1240			540.0	350.0					
MOE	77	22-Aug	S16	Lower Myers Creek	1540			>2400	>2400					
MOE	77	24-Aug	S16	Lower Myers Creek	1140			920.0	540.0					
MOE	77	29-Aug	S16	Lower Myers Creek	1010	15.0		230.0	130.0					
MOE	77	31-Aug	S16	Lower Myers Creek	1245	14.0		230.0	50.0					
MOE	77	7-Sep	S16	Lower Myers Creek	1410	13.0		540.0	170.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
MOE	77	12-Sep	S16	Lower Myers Creek	1555	14.5		50.0	20.0					
MOE	77	14-Sep	S16	Lower Myers Creek	1155	14.0		140.0	70.0					
MOE	77	19-Sep	S16	Lower Myers Creek	1545	12.0		330.0	130.0					
MOE	77	21-Sep	S16	Lower Myers Creek	1310	12.0		130.0	50.0					
MOE	77	26-Sep	S16	Lower Myers Creek	1620	11.0		80.0	50.0					
MOE	77	28-Sep	S16	Lower Myers Creek	1150	10.0		20.0	<20	330.0	159.6	130.0	86.7	26.7
MOE	77	8-Aug	S17	Upper Myers Creek	1710			33.0	5.0					
MOE	77	10-Aug	S17	Upper Myers Creek	1205			70.0	22.0					
MOE	77	15-Aug	S17	Upper Myers Creek	1550			70.0	17.0					
MOE	77	17-Aug	S17	Upper Myers Creek	1255			33.0	13.0					
MOE	77	22-Aug	S17	Upper Myers Creek	1550			130.0	8.0					
MOE	77	24-Aug	S17	Upper Myers Creek	1150			33.0	11.0					
MOE	77	29-Aug	S17	Upper Myers Creek	1625	14.5		63.0	8.0					
MOE	77	31-Aug	S17	Upper Myers Creek	1300	14.0		33.0	8.0					
MOE	77	7-Sep	S17	Upper Myers Creek	1425	12.5		46.0	4.0					
MOE	77	12-Sep	S17	Upper Myers Creek	1620	13.0		13.0	<2					
MOE	77	14-Sep	S17	Upper Myers Creek	1315	13.0		33.0	5.0					
MOE	77	19-Sep	S17	Upper Myers Creek	1610	12.0		350.0	79.0					
MOE	77	21-Sep	S17	Upper Myers Creek	1330	10.5		49.0	33.0					
MOE	77	26-Sep	S17	Upper Myers Creek	1640	11.0		23.0	5.0					
MOE	77	28-Sep	S17	Upper Myers Creek	1205	10.0		70.0	5.0	46.0	9.3	8.0	6.7	0.0
CGH	78		S1	Mouth of Malaspina Cr.							136.0	93.0		18.2
CGH	78		S3	S. Fork of Malaspina Cr.							4.0	<3		9.1
CGH	78		S4	Malaspina Creek							124.0	75.0		27.3
CGH	78		S6	N. Fork of Malaspina Cr.							21.0	23.0		9.1
CGH	78		S7	Mouth of unnamed creek							109.0	93.0		18.2
CGH	78		S8	Unnamed creek-East Bay							78.0	93.0		18.2
CGH	78		S9	Anderson Creek							26.0	23.0		9.1
CGH	78		S10	Anderson Cr. at road							22.0	23.0		0.0
CGH	78		S11	Anderson Cr. at highway							7.0	9.0		0.0
CGH	78		S12	Trib. to Anderson Cr.							21.0	15.5		0.0
CGH	78		S13	Kleindale Cr. at highway							3.0	<3		0.0
CGH	78		S14	Myers Creek at mouth							13.0	9.0		0.0
CGH	78		S15	Myers Creek							134.0	93.0		18.2
CGH	78		S16	Myers Cr. at road							39.0	43.0		9.1
CGH	78		S17	Myers Cr. at highway							10.0	9.0		0.0
CGH	78		S19	Unnamed Cr.-Oyster Bay							118.0	151.5		30.0
EPS	81	1-Sep	1	Head of East Bay	0925		25.0		22.0					
EPS	81	2-Sep	1	Head of East Bay	0950		24.5		13.0					
EPS	81	3-Sep	1	Head of East Bay	1050		14.5		920.0		64.1	22.0	33.3	33.3
EPS	81	1-Sep	3	Mouth of East Bay	0935		24.5		170.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
EPS	81	2-Sep	3	Mouth of East Bay	0955		24.0		79.0					
EPS	81	3-Sep	3	Mouth of East Bay	1050		25.0		<2		29.9	79.0	66.7	0.0
EPS	81	1-Sep	6	Oyster Bay	0915		24.0		79.0					
EPS	81	2-Sep	6	Oyster Bay	0940		21.0		17.0					
EPS	81	3-Sep	6	Oyster Bay	1045		25.0		7.0		21.1	17.0	33.3	0.0
EPS	81	1-Sep	8	Oyster Bay	0900		24.0		46.0					
EPS	81	2-Sep	8	Oyster Bay	0910		25.0		<2					
EPS	81	3-Sep	8	Oyster Bay	1020		23.0		8.0		9.0	8.0	33.3	0.0
EPS	81	1-Sep	9	Oyster Bay	0905		8.0		540.0					
EPS	81	2-Sep	9	Oyster Bay	0925		4.0		130.0					
EPS	81	3-Sep	9	Oyster Bay	1025		3.5		350.0		290.7	350.0	100.0	33.3
EPS	81	28-Aug	10	Oyster Bay	1745		25.0		8.0					
EPS	81	31-Aug	10	Oyster Bay	0855		25.5		8.0					
EPS	81	1-Sep	10	Oyster Bay	0855		25.5		8.0					
EPS	81	2-Sep	10	Oyster Bay	0910		25.5		4.0					
EPS	81	3-Sep	10	Oyster Bay	1020		25.0		2.0		5.3	8.0	0.0	0.0
EPS	81	28-Aug	11	Oyster Bay	1740		25.0		7.0					
EPS	81	31-Aug	11	Oyster Bay	0850		26.0		79.0					
EPS	81	1-Sep	11	Oyster Bay	0850		25.5		70.0					
EPS	81	2-Sep	11	Oyster Bay	0905		25.5		13.0					
EPS	81	3-Sep	11	Oyster Bay	1020		25.0		8.0		20.9	13.0	40.0	0.0
EPS	81	28-Aug	12	Oyster Bay	1740		25.0		17.0					
EPS	81	31-Aug	12	Oyster Bay	0845		26.0		11.0					
EPS	81	1-Sep	12	Oyster Bay	0850		25.0		70.0					
EPS	81	2-Sep	12	Oyster Bay	0905		23.5		79.0					
EPS	81	3-Sep	12	Oyster Bay	1015		23.0		2.0		18.3	17.0	40.0	0.0
EPS	81	18-Feb	13	Oyster Bay	0925		10.5		8.0					
EPS	81	20-Feb	13	Oyster Bay	0845		11.5		130.0					
EPS	81	23-Feb	13	Oyster Bay	0900		20.0		<2					
EPS	81	24-Feb	13	Oyster Bay	0845		18.0		2.0		8.0	5.0	25.0	0.0
EPS	81	28-Aug	13	Oyster Bay	1740		25.0		2.0					
EPS	81	31-Aug	13	Oyster Bay	0845		26.0		46.0					
EPS	81	1-Sep	13	Oyster Bay	0845		25.5		49.0					
EPS	81	2-Sep	13	Oyster Bay	0900		25.0		8.0					
EPS	81	3-Sep	13	Oyster Bay	1015		25.0		8.0		12.4	8.0	40.0	0.0
EPS	81	18-Feb	15	Oyster Bay	0925		14.0		22.0					
EPS	81	20-Feb	15	Oyster Bay	0840		11.5		17.0					
EPS	81	23-Feb	15	Oyster Bay	0900		19.0		2.0					
EPS	81	24-Feb	15	Oyster Bay	0840		16.5		2.0		6.2	9.5	0.0	0.0
EPS	81	8-Aug	15	Oyster Bay	1730		25.0		2.0					
EPS	81	31-Aug	15	Oyster Bay	0845		26.0		8.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDING 400/100 mL
EPS	81	1-Sep	15	Oyster Bay	0845		25.5		110.0					
EPS	81	2-Sep	15	Oyster Bay	0855		24.0		8.0					
EPS	81	3-Sep	15	Oyster Bay	1010		24.0		5.0		9.3	8.0	20.0	0.0
EPS	81	28-Aug	16	Oyster Bay	1735		25.0		2.0					
EPS	81	31-Aug	16	Oyster Bay	0840		25.5		23.0					
EPS	81	1-Sep	16	Oyster Bay	0840		25.5		49.0					
EPS	81	2-Sep	16	Oyster Bay	0900		24.5		33.0					
EPS	81	3-Sep	16	Oyster Bay	1010		24.5		23.0		17.6	23.0	20.0	0.0
EPS	81	28-Aug	17	Oyster Bay	1735		25.0		7.0					
EPS	81	31-Aug	17	Oyster Bay	0840		25.5		2.0					
EPS	81	1-Sep	17	Oyster Bay	0840		25.0		33.0					
EPS	81	2-Sep	17	Oyster Bay	0900		25.0		79.0					
EPS	81	3-Sep	17	Oyster Bay	1015		25.0		8.0		12.4	8.0	20.0	0.0
EPS	81	2-Sep	S1	Mouth of Malaspina Cr.					70.0					
EPS	81	3-Sep	S1	Mouth of Malaspina Cr.					51.0		59.7	60.5	100.0	0.0
EPS	81	1-Sep	S3	S. Fork Malaspina Cr.					10.0					
EPS	81	2-Sep	S3	S. Fork Malaspina Cr.					6.0					
EPS	81	3-Sep	S3	S. Fork Malaspina Cr.					3.0		5.7	6.0	0.0	0.0
EPS	81	1-Sep	S6	N. Fork Malaspina Cr.					20.0					
EPS	81	2-Sep	S6	N. Fork Malaspina Cr.					262.0					
EPS	81	3-Sep	S6	N. Fork Malaspina Cr.					9.0		36.1	20.0	33.3	0.0
EPS	81	2-Sep	S7	Unnamed cr.-East Bay					110.0					
EPS	81	3-Sep	S7	Unnamed cr.-East Bay					51.0		74.9	80.5	100.0	0.0
EPS	81	1-Sep	S10	Anderson Creek					20.0					
EPS	81	2-Sep	S10	Anderson Creek					21.0					
EPS	81	3-Sep	S10	Anderson Creek					9.0		15.6	20.0	0.0	0.0
EPS	81	1-Sep	S11	Anderson Cr. at highway					20.0					
EPS	81	2-Sep	S11	Anderson Cr. at highway					21.0					
EPS	81	3-Sep	S11	Anderson Cr. at highway					9.0		15.6	20.0	0.0	0.0
EPS	81	1-Sep	S13	Kleindale Cr. at highway					<10					
EPS	81	2-Sep	S13	Kleindale Cr. at highway					1.0					
EPS	81	3-Sep	S13	Kleindale Cr. at highway					0.0		2.2	1.0	0.0	0.0
EPS	81	1-Sep	S14	Mouth of Myers Creek					160.0					
EPS	81	2-Sep	S14	Mouth of Myers Creek					80.0					
EPS	81	3-Sep	S14	Mouth of Myers Creek					20.0		63.5	80.0	66.7	0.0
EPS	81	2-Sep	S17	Myers Cr. at highway					10.0					
EPS	81	3-Sep	S17	Myers Cr. at highway					1.0		3.2	5.5	0.0	0.0
EPS	81	1-Sep	S18	Unnamed cr.- Oyster Bay					600.0					
EPS	81	2-Sep	S18	Unnamed cr.- Oyster Bay					310.0					
EPS	81	3-Sep	S18	Unnamed cr.- Oyster Bay					70.0		235.3	310.0	100.0	33.3
EPS	81	2-Sep	S20	Unnamed cr.-Oyster Bay					<10					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDIN 43/100 mL	% EXCEEDIN 400/100 mL
EPS	81	3-Sep	S20	Unnamed cr.-Oyster Bay					3.0		5.5	6.5	0.0	0.0
EPS	81	1-Sep	S21	Highway and road					3000.0					
EPS	81	2-Sep	S21	Highway and road					2300.0					
EPS	81	3-Sep	S21	Highway and road					1090.0		1959.3	2300.0	100.0	100.0
CGHU	87	10-Jun	24	Garden Bay					<3					
CGHU	87	24-Jun	24	Garden Bay					<3					
CGHU	87	21-Jul	24	Garden Bay					<3					
CGHU	87	12-Aug	24	Garden Bay					4.0					
CGHU	87	18-Aug	24	Garden Bay					43.0		5.4	3.0	0.0	0.0
CGHU	87	10-Jun	39	Lowes Resort					43.0					
CGHU	87	24-Jun	39	Lowes Resort					9.0					
CGHU	87	8-Jul	39	Lowes Resort					28.0					
CGHU	87	21-Jul	39	Lowes Resort					<3					
CGHU	87	4-Aug	39	Lowes Resort					9.0					
CGHU	87	18-Aug	39	Lowes Resort					23.0		13.7	16.0	0.0	0.0
CGHU	88	13-Jun	24	Garden Bay					<3					
CGHU	88	28-Jun	24	Garden Bay					<3					
CGHU	88	12-Jul	24	Garden Bay					<3					
CGHU	88	9-Aug	24	Garden Bay					<3					
CGHU	88	23-Aug	24	Garden Bay					<3		3.0	3.0	0.0	0.0
CGHU	88	13-Jun	39	Lowes Resort					<3					
CGHU	88	28-Jun	39	Lowes Resort					23.0					
CGHU	88	12-Jul	39	Lowes Resort					150.0					
CGHU	88	26-Jul	39	Lowes Resort					93.0					
CGHU	88	9-Aug	39	Lowes Resort					21.0					
CGHU	88	23-Aug	39	Lowes Resort					<3		19.8	22.0	33.3	0.0
EPS	89	23-Oct	7	Oyster Bay	1225		0.0		170.0					
EPS	89	24-Oct	7	Oyster Bay	1420		2.0		170.0					
EPS	89	25-Oct	7	Oyster Bay	1245		3.5		79.0					
EPS	89	27-Oct	7	Oyster Bay	1315		3.0		130.0					
EPS	89	30-Oct	7	Oyster Bay	1140		19.0		49.0		107.8	130.0	100.0	0.0
EPS	89	23-Oct	9	Oyster Bay	1230		0.0		79.0					
EPS	89	24-Oct	9	Oyster Bay	1420		0.0		130.0					
EPS	89	25-Oct	9	Oyster Bay	1245		2.0		170.0					
EPS	89	30-Oct	9	Oyster Bay	1145		8.0		170.0		131.3	150.0	100.0	0.0
EPS	89	23-Oct	12	Oyster Bay	1220		7.5		350.0					
EPS	89	24-Oct	12	Oyster Bay	0850		0.0		350.0					
EPS	89	25-Oct	12	Oyster Bay	1240		12.5		350.0					
EPS	89	27-Oct	12	Oyster Bay	1305		11.0		130.0					
EPS	89	30-Oct	12	Oyster Bay	1125		12.0		170.0		248.5	350.0	100.0	0.0
EPS	89	23-Oct	14	Oyster Bay	1200		12.0		540.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDIN 43/100 mL	% EXCEEDIN 400/100 mL
EPS	89	24-Oct	14	Oyster Bay	0845		4.0		170.0					
EPS	89	25-Oct	14	Oyster Bay	1240		17.0		540.0					
EPS	89	27-Oct	14	Oyster Bay	1300		11.0		130.0					
EPS	89	30-Oct	14	Oyster Bay	1120		21.0		49.0		199.5	170.0	100.0	40.0
EPS	89	24-Oct	45	Bargain Bay	0955		28.0		13.0					
EPS	89	25-Oct	45	Bargain Bay	1610		27.0		8.0					
EPS	89	26-Oct	45	Bargain Bay	1110		29.0		<2					
EPS	89	27-Oct	45	Bargain Bay	1220		27.0		2.0					
EPS	89	28-Oct	45	Bargain Bay	1045		27.5		<2		3.8	2.0	0.0	0.0
EPS	89	24-Oct	46	Bargain Bay	0955		26.0		49.0					
EPS	89	25-Oct	46	Bargain Bay	1615		27.0		11.0					
EPS	89	26-Oct	46	Bargain Bay	1110		28.0		2.0					
EPS	89	27-Oct	46	Bargain Bay	1220		26.5		<2					
EPS	89	28-Oct	46	Bargain Bay	1050		28.0		<2		5.3	2.0	20.0	0.0
EPS	89	24-Oct	47	Bargain Bay	0950		26.0		8.0					
EPS	89	25-Oct	47	Bargain Bay	1620		26.5		<2					
EPS	89	26-Oct	47	Bargain Bay	1105		28.0		2.0					
EPS	89	27-Oct	47	Bargain Bay	1215		27.0		<2					
EPS	89	28-Oct	47	Bargain Bay	1055		28.0		<2		2.6	2.0	0.0	0.0
EPS	89	24-Oct	49	Bargain Bay	0945		28.0		13.0					
EPS	89	25-Oct	49	Bargain Bay	1525		27.5		5.0					
EPS	89	26-Oct	49	Bargain Bay	1100		28.0		11.0					
EPS	89	27-Oct	49	Bargain Bay	1210		26.0		8.0					
EPS	89	28-Oct	49	Bargain Bay	1100		28.0		<2		6.5	8.0	0.0	0.0
EPS	89	24-Oct	51	Bargain Bay	1000		28.0		2.0					
EPS	89	25-Oct	51	Bargain Bay	1535		28.0		2.0					
EPS	89	26-Oct	51	Bargain Bay	1115		30.0		8.0					
EPS	89	27-Oct	51	Bargain Bay	1200		27.0		<2					
EPS	89	28-Oct	51	Bargain Bay	1105		28.0		2.0		2.6	2.0	0.0	0.0
EPS	89	24-Oct	52	Bargain Bay	1005		28.0		7.0					
EPS	89	25-Oct	52	Bargain Bay	1550		27.0		2.0					
EPS	89	26-Oct	52	Bargain Bay	1120		29.0		5.0					
EPS	89	27-Oct	52	Bargain Bay	1155		27.5		<2					
EPS	89	28-Oct	52	Bargain Bay	1110		28.0		2.0		3.1	2.0	0.0	0.0
EPS	89	24-Oct	54	Bargain Bay	1005		28.0		7.0					
EPS	89	25-Oct	54	Bargain Bay	1605		27.5		5.0					
EPS	89	26-Oct	54	Bargain Bay	1125		28.0		<2					
EPS	89	27-Oct	54	Bargain Bay	1155		28.0		2.0					
EPS	89	28-Oct	54	Bargain Bay	1115		28.0		<2		3.1	2.0	0.0	0.0
EPS	90	14-Aug	7	Oyster Bay	1325		21.0		4.0					
EPS	90	16-Aug	7	Oyster Bay	1610		22.0		2.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDING 43/100 mL	% EXCEEDIN 400/100 mL
EPS	90	17-Aug	7	Oyster Bay	1540		22.0		13.0					
EPS	90	18-Aug	7	Oyster Bay	1615		23.0		2.0					
EPS	90	23-Aug	7	Oyster Bay	0750		22.0		8.0		4.4	4.0	0.0	0.0
EPS	90	14-Aug	9	Oyster Bay	1325		21.0		2.0					
EPS	90	16-Aug	9	Oyster Bay	1615		22.0		2.0					
EPS	90	17-Aug	9	Oyster Bay	1545		22.0		4.0					
EPS	90	18-Aug	9	Oyster Bay	1615		22.0		13.0					
EPS	90	23-Aug	9	Oyster Bay	0755		22.0		5.0		4.0	4.0	0.0	0.0
EPS	90	14-Aug	12	Oyster Bay	1330		21.0		2.0					
EPS	90	16-Aug	12	Oyster Bay	1605		22.0		5.0					
EPS	90	17-Aug	12	Oyster Bay	1535		22.0		4.0					
EPS	90	18-Aug	12	Oyster Bay	1610		23.0		4.0					
EPS	90	23-Aug	12	Oyster Bay	0745		22.0		23.0		5.2	4.0	0.0	0.0
EPS	90	14-Aug	14	Oyster Bay	1335		21.0		<2					
EPS	90	16-Aug	14	Oyster Bay	1600		22.0		2.0					
EPS	90	17-Aug	14	Oyster Bay	1530		22.0		11.0					
EPS	90	18-Aug	14	Oyster Bay	1610		23.0		2.0					
EPS	90	23-Aug	14	Oyster Bay	0800		22.0		14.0		4.2	2.0	0.0	0.0
EPS	90	15-Aug	45	Bargain Bay	0710		22.0		<2					
EPS	90	16-Aug	45	Bargain Bay	1455		21.0		<2					
EPS	90	17-Aug	45	Bargain Bay	0915		23.0		2.0					
EPS	90	18-Aug	45	Bargain Bay	0905		23.0		2.0					
EPS	90	19-Aug	45	Bargain Bay	0715		22.0		6.0		2.5	2.0	0.0	0.0
EPS	90	15-Aug	46	Bargain Bay	0710		21.0		46.0					
EPS	90	16-Aug	46	Bargain Bay	1500		21.0		2.0					
EPS	90	17-Aug	46	Bargain Bay	0920		23.0		<2					
EPS	90	18-Aug	46	Bargain Bay	0905		23.0		7.0					
EPS	90	19-Aug	46	Bargain Bay	0710		20.0		79.0		10.0	7.0	40.0	0.0
EPS	90	15-Aug	47	Bargain Bay	0715		22.0		5.0					
EPS	90	16-Aug	47	Bargain Bay	1505		22.0		<2					
EPS	90	17-Aug	47	Bargain Bay	0920		23.0		<2					
EPS	90	18-Aug	47	Bargain Bay	0910		23.0		2.0					
EPS	90	19-Aug	47	Bargain Bay	0710		23.0		7.0		3.1	2.0	0.0	0.0
EPS	90	15-Aug	49	Bargain Bay	0720		21.0		2.0					
EPS	90	16-Aug	49	Bargain Bay	1505		22.0		<2					
EPS	90	17-Aug	49	Bargain Bay	0925		23.0		<2					
EPS	90	18-Aug	49	Bargain Bay	0910		23.0		7.0					
EPS	90	19-Aug	49	Bargain Bay	0705		22.0		11.0		3.6	2.0	0.0	0.0
EPS	90	15-Aug	51	Bargain Bay	0725		22.0		4.0					
EPS	90	16-Aug	51	Bargain Bay	1455		22.0		<2					
EPS	90	17-Aug	51	Bargain Bay	0915		23.0		2.0					

Appendix I. Bacteriological Data for Pender Harbour

AGENCY	YEAR	DAY	STATION NUMBER	STATION LOCATION	TIME	TEMP (°C)	SAL (ppt)	TOTAL COLIF (MPN/100 mL)	FECAL COLIF (MPN/100 mL)	TOTAL MEDIAN	FECAL GEO. MEAN	FECAL MEDIAN	% EXCEEDIN 43/100 mL	% EXCEEDIN 400/100 mL
EPS	90	18-Aug	51	Bargain Bay	0900		23.0		2.0					
EPS	90	19-Aug	51	Bargain Bay	0715		23.0		8.0		3.0	2.0	0.0	0.0
EPS	90	15-Aug	52	Bargain Bay	0730		22.0		<2					
EPS	90	16-Aug	52	Bargain Bay	1450		22.0		<2					
EPS	90	17-Aug	52	Bargain Bay	0910		23.0		5.0					
EPS	90	18-Aug	52	Bargain Bay	0855		24.0		4.0					
EPS	90	19-Aug	52	Bargain Bay	0720		24.0		23.0		4.5	4.0	0.0	0.0
EPS	90	15-Aug	54	Bargain Bay	0735		22.0		<2					
EPS	90	16-Aug	54	Bargain Bay	1445		22.0		31.0					
EPS	90	17-Aug	54	Bargain Bay	0905		23.0		<2					
EPS	90	18-Aug	54	Bargain Bay	0855		24.0		<2					
EPS	90	19-Aug	54	Bargain Bay	0725		24.0		2.0		3.5	2.0	0.0	0.0
EPS	91	May	7	Oyster Bay								17.0		
EPS	91	May	9	Oyster Bay								23.0		
EPS	91	May	12	Oyster Bay								23.0		
EPS	91	May	14	Oyster Bay								2.0		
EPS	91	May	45	Bargain Bay								<2		
EPS	91	May	46	Bargain Bay								<2		
EPS	91	May	47	Bargain Bay								<2		
EPS	91	May	49	Bargain Bay								<2		
EPS	91	May	51	Bargain Bay								<2		
EPS	91	May	52	Bargain Bay								<2		
EPS	91	May	54	Bargain Bay								<2		

APPENDIX II

Ammonia Criteria Tables

TABLE A

MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF SALTWATER AQUATIC LIFE (mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	270	191	131	92	62	44
7.2	175	121	83	58	40	27
7.4	110	77	52	35	25	17
7.6	69	48	33	23	16	11
7.8	44	31	21	15	10	7.1
8.0	27	19	13	9.4	6.4	4.6
8.2	18	12	8.5	5.8	4.2	2.9
8.4	11	7.9	5.4	3.7	2.7	1.9
8.6	7.3	5.0	3.5	2.5	1.8	1.3
8.8	4.6	3.3	2.3	1.7	1.2	0.92
9.0	2.9	2.1	1.5	1.1	0.85	0.67
	Salinity = 20 g/kg					
7.0	291	200	137	96	64	44
7.2	183	125	87	60	42	29
7.4	116	79	54	37	27	18
7.6	73	50	35	23	17	11
7.8	46	31	23	15	11	7.5
8.0	29	20	14	9.8	6.7	4.8
8.2	19	13	8.9	6.2	4.4	3.1
8.4	12	8.1	5.6	4.0	2.9	2.0
8.6	7.5	5.2	3.7	2.7	1.9	1.4
8.8	4.8	3.3	2.5	1.7	1.3	0.94
9.0	3.1	2.3	1.6	1.2	0.87	0.69
	Salinity = 30 g/kg					
7.0	312	208	148	102	71	48
7.2	196	135	94	64	44	31
7.4	125	85	58	40	27	19
7.6	79	54	37	25	21	12
7.8	50	33	23	16	11	7.9
8.0	31	21	15	10	7.3	5.0
8.2	20	14	9.6	6.7	4.6	3.3
8.4	12.7	8.7	6.0	4.2	2.9	2.1
8.6	8.1	5.6	4.0	2.7	2.0	1.4
8.8	5.2	3.5	2.5	1.8	1.3	1.0
9.0	3.3	2.3	1.7	1.2	0.94	0.71

g/kg salinity is equivalent to parts per thousand (ppt or $^{0}/_{00}$)

TABLE B

AVERAGE 5 TO 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF SALTWATER AQUATIC LIFE (mg/L-N)

	Temperature (°C)					
	0	5	10	15	20	25
pH	Salinity = 10 g/kg					
7.0	41	29	20	14	9.4	6.6
7.2	26	18	12	8.7	5.9	4.1
7.4	17	12	7.8	5.3	3.7	2.6
7.6	10	7.2	5.0	3.4	2.4	1.7
7.8	6.6	4.7	3.1	2.2	1.5	1.1
8.0	4.1	2.9	2.0	1.40	0.97	0.69
8.2	2.7	1.8	1.3	0.87	0.62	0.44
8.4	1.7	1.2	0.81	0.56	0.41	0.29
8.6	1.1	0.75	0.53	0.37	0.27	0.20
8.8	0.69	0.50	0.34	0.25	0.18	0.14
9.0	0.44	0.31	0.23	0.17	0.13	0.10
	Salinity = 20 g/kg					
7.0	44	30	21	14	9.7	6.6
7.2	27	19	13	9.0	6.2	4.4
7.4	18	12	8.1	5.6	4.1	2.7
7.6	11	7.5	5.3	3.4	2.5	1.7
7.8	6.9	4.7	3.4	2.3	1.6	1.1
8.0	4.4	3.0	2.1	1.5	1.0	0.72
8.2	2.8	1.9	1.3	0.94	0.66	0.47
8.4	1.8	1.2	0.84	0.59	0.44	0.30
8.6	1.1	0.78	0.56	0.41	0.28	0.20
8.8	0.72	0.50	0.37	0.26	0.19	0.14
9.0	0.47	0.34	0.24	0.18	0.13	0.10
	Salinity = 30 g/kg					
7.0	47	31	22	15	11.	7.2
7.2	29	20	14	9.7	6.6	4.7
7.4	19	13	8.7	5.9	4.1	2.9
7.6	12	8.1	5.6	3.7	3.1	1.8
7.8	7.5	5.0	3.4	2.4	1.7	1.2
8.0	4.7	3.1	2.2	1.6	1.1	0.75
8.2	3.0	2.1	1.4	1.0	0.69	0.50
8.4	1.9	1.3	0.90	0.62	0.44	0.31
8.6	1.2	0.84	0.59	0.41	0.30	0.22
8.8	0.78	0.53	0.37	0.27	0.20	0.15
9.0	0.50	0.34	0.26	0.19	0.14	0.11

The criterion value is obtained by using the average pH, temperature and salinity field values, and is compared to the mean of the measured ammonia concentrations.